DOCUMENT RESUME

ED 121 954 CE 006 696

AUTHOR Schorgmayer, Helmut; Swanson, Richard A.
TITLE The Effect of Alternative Training Methods on the Trouble-Shooting Performances of Maintenance Technicians.
INSTITUTION Bowling Green State Univ., Ohio.; Johns-Manville Corp., Denver, Colo.
PUB DATE Aug 75
NOTE 150p.; Not available in hard copy due to marginal reproducibility

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS *Autoinstructional Aids; *Comparative Analysis; *Equipment Maintenance; Fluid Power Education; Job Training; Machine Repairmen; Mechanics (Process); Research; Simulation; Tests; *Training Techniques
IDENTIFIERS *Troubleshooting

ABSTRACT

Results of a study to determine the effects of conceptual versus specific (traditional) training techniques on the trouble-shooting performance of maintenance technicians are presented. The research subjects were students at Bowling Green State University and citizens in Northwest Ohio with no post high school technical coursework. Those that scored in the middle range of the Bennet Mechanical Comprehension Test were divided into three groups, with one using the conceptual self instructional module, one the specific self-instructional module, and one receiving no training at all. Trouble-shooting performances for all three groups were measured on a simulator representing a common production machine. Results indicate that both training programs were equally effective, and both trained groups performed significantly better, than the control group. An introduction, review of the literature, procedures, analysis and discussion of the data, summary and conclusions, and bibliography are presented. Appended material takes up the bulk of the document and includes: self-instructional modules for fluid systems and mechanization; decision matrix for instruction criterion; validation form; performance test simulator; oral introduction script to the simulator; research recruitment tools: application form; title page from the Bennet Mechanical Comprehension Test; attitude inventory; and, project flowchart. (LH)

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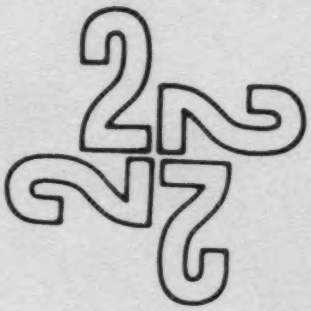
THE EFFECT OF ALTERNATIVE TRAINING METHODS ON THE TROUBLE-SHOOTING PERFORMANCES OF MAINTENANCE TECHNICIANS

Helmut Schörgmayer
Richard A. Swanson

INDUSTRIAL TRAINING RESEARCH



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AUGUST 1975

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ABSTRACT

The increasing sophistication of production machinery and the corresponding increase in the difficulty of the tasks of maintenance technicians creates training problems for maintenance personnel. This study was concerned with the effects of conceptual versus specific (traditional) training on the trouble-shooting performance of maintenance technicians.

A three group posttest experimental design was used to assess the hypotheses. Two Self Instructional Modules representing the two competing approaches to training for trouble-shooting were developed. Trouble-shooting performance was measured on a simulator that represented a common production machine.

There was no significant difference (.05 level) in the trouble-shooting performance of trainees that received specific training and trainees that received conceptual training. Both treatment groups performed significantly better (.001 level) than the control group.

The study concluded that the type of training (specific or conceptual) had little effect on the trouble-shooting performance of maintenance technicians. Both training programs were equally effective. Based on the findings and observations by the researcher, recommendations for further research were made in the areas of 1) economic feasibility of job performance aids; 2) repetition of this study on a larger scale; and 3) the development and validation of a trouble-shooting attitude test battery.

ACKNOWLEDGEMENTS

Cooperative efforts are always special. This research study was no exeption. We acknowledge the financial assistance provided by Johns-Manville Corporation and the support from their corporate training personnel, Gil Cullen and Gary Sisson; Brodhead-Garrett Company and Thomas Rogers for the loan of equipment; and professor Arthony Palumbo, Bowling Green State University, for his technical assistance.

The area of training for trouble-shooting is open for interpretation and a great deal of research. It is hoped that this study will lead to continued efforts in the pursuit of an optimal system for training maintenance trouble-shooting personnel.

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Principal Investigator

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CHAPTER I

INTRODUCTION

Nature of the Problem

Sophisticated technology is used in almost all branches of industry. Because of this, well functioning maintenance of expensive equipment becomes increasingly important.

Along with this, the difficulty of the maintenance technician's job is growing at the same pace as the complexity of the equipment. One result is a difficulty in obtaining qualified personnel in the labor market. Because of this situation, many industries have developed their own training progams to upgrade their personnel and train new employees. At the same time, institutions of vocational and technical education have developed strategies that are designed to quality their graduates to work in the area of industrial mainterance.

It is gererally agreed that the most difficult part of the work of a maintenance technician is the task of localizing malfunctions within a system or equipment that fails. This process is often called trouble-shooting. It involves higher cognitive behaviors, such as analyzing, synthesizing and decision making. It also requires some specialized knowledge that changes from equipment to equipment.

Generally, maintenance technicians have learned their trade on the job, but because of increased cost and the questionable quality of this approach (Swanson & Sawzin,

1975), formal training for maintenance technicians is becoming more popular. The methods used in these training programs are varied and go from specialized training on a particular piece of equipment to general topics such as physics, mathematics and mechanics.

While technology and related trouble-shooting jobs are increasing in complexity, little is known about the effectiveness of alternative training methods.

Statement of the Problem

This study was concerned with the effects of conceptual versus specific (traditional) training on the trouble-shooting performance of maintenance technicians.

Sub-Problems

1. To identify the principal components of production machines through a logical analysis of their systems.
2. To develop an arrangement of components into a simulator that represents a typical system found in production machines.
3. To develop a test that measures trouble-shooting performance, using the simulator.
4. To develop a method for evaluating the attitudes of trainees toward the job.
5. To develop a short training course on the concepts that underly the function of machines (conceptual approach) and the systematic procedures used for trouble-shooting.

6. To develop a short training course about one particular part of the simulated system (specific approach) and the systematic procedures used for trouble-shooting.

7. To select trainees for the two experimental groups and the control group.

8. To execute the experiment.

9. To collect and analyze the following data so as to evaluate the effectiveness of the two approaches to training for the task of trouble-shooting:

   a. Performance (based upon whether the problem is localized or not and the time taken for trouble-shooting) of the two groups on equipment treated in the "specific approach" training.

   b. Performance of the two groups on equipment not familiar to both groups.

   c. The attitude of the trainees that received conceptual training toward the trouble-shooting experience versus those with the specific training.

Significance of the Problem

A good maintenance organization is essential for the functioning of a company (Training Electrical, 1971), and a good maintenance organization needs skilled technicians that can catch up easily with new technology.

In order to have skilled and easily adaptable technicians, high quality training programs need to be developed.

There is little research done on the subject of trouble-shooting in general, and no serious study on how the knowledge of concepts affects the performance of maintenance personnel could be found.

Limitations of the Study

This study is limited by the size of the three treatment groups, the scope of the two training programs and the profile of the trainees. These factors are discussed in detail in Chapter III.

DEFINITION OF TERMS

Trouble-shooting: Trouble-shooting is the process of localizing the defective element(s) that cause(s) the malfunction of equipment or a system.

Conceptual approach: The conceptual approach to trouble-shooting training teaches a general overview of the principal components (electrical, mechanical or fluid) that compose machines or systems, their interrelations and the flow of power or/and information through the system.

Specific approach: The specific approach to trouble-shooting training treats only one of the three types of components (electrical, mechanical or fluid) that are found in machines. It begins with the basic principles of a technical subject, treats the components in detail and gives indications about trouble-shooting procedures for only that particular component.

Failure rate: The failure rate is a measure of the probability of failure in a particular part that is based on previous experience.

Simulator: A simulator is an assembly of equipment that represents an on-line machine, equipment, or system in a simplified manner. It is normally used for training of particular tasks that have to be performed on the on-line equipment.

CHAPTER II

REVIEW OF THE LITERATURE

The Need for Training Maintenance Personnel

The increased automation of industrial processes and the resulting sophistication of the equipment made maintenance a key function of an industrial enterprise (Zollitsch, 1954). While the maintenance function has gained in importance, the job of maintenance personnel has become equally difficult. More effective initial training and constant upgrading of skills and knowledge is considered essential if maintenance personnel are to keep up with their responsibilities (Oliverson, 1973). In a survey at Kaiser Aluminum Corporation, 71% of the maintenance personnel were reported to need refresher training. Their knowledge had become partially obsolete (Oliverson, 1971).

New workers, even when they are fully trained journeymen, need adjustment periods of up to two years when they are assigned to the maintenance function (International, 1967, p.23). During this time they work usually as assistants to an experienced technician. This adjustment time is partially due to inefficient training methods. Most maintenance workers learn their trade through on-the-job training (International, 1967; US Department, 1974, p.445). This

method has several significant shortcomings. For example, it prolongs the time which new employees need to acquire proficiency. Parallel to that disadvantage is the fact that there is no security about their future performance, since they did not receive a well-rounded knowledge and skills (Swanson and Sawzin, 1975; U.S. Department, 1971).

Many companies provide structured training for their maintenance personnel that covers a wide variety of subjects. Some industries offer periodically in-plant training courses in general technical subjects to broaden the background of their maintenance workers (The Payoff, 1972). In another method, the same objective is pursued by companies that offer financial assistance to employees that attend classes in educational institutions, or who attend correspondence schools in their spare time (Training electrical, 1971; Worster, 1970).

When new equipment is installed in a factory, it is of utmost importance to make the maintenance people familiar with the machinery before it goes into operation. Training for this purpose is often provided by the supplier of the equipment. It is offered in the form of formal training courses or as on-site demonstrations during the installation of the equipment (International, 1967, p.25).

Training for Trouble-Shooting

The job of a maintenance technician includes tasks of preventive and corrective maintenance. The latter is more critical since it includes diagnostic tasks, commonly called trouble-shooting. These are considered the most important part of the work of maintenance technicans (Glanzer, 1958, p.237; International, 1967, p.23). Therefore, the major portion of the training effort for maintenance personnel should be directed towards the improvement of their trouble-shooting abilities.

This logic is not always followed. There is little information on teaching methods for trouble-shooting and it often needs costly equipment that facilitates the insertion of malfunctions. Even when there is a management commitment to the costly training equipment, problems arise as to the faithful representation of the original equipment (French, 1956). Because of these difficulties, many training programs emphasize theoretical knowledge about a specific system. From this it is hoped that with a core of very specific knowledge and skills a technician can deduce a solution to a trouble-shooting problem by analyzing the system (Shriver, Fink and Trexler, 1964).

Another approach is to teach a broad core of general knowledge related to the job and provide the specific information through job performance aids prepared for each type of equipment (Gebhard, 1973; Foley and Camm, 1972). There

is some evidence that the job performance aid approach facilitates the transfer of skills to unfamiliar equipment (Shriver et al., 1964).

Factors that are believed to have influence upon the trouble-shooting performance of maintenance personnel are: knowledge of functional relationship among components, ability for logical analysis, familiarity with the equipment, skills in the use of test equipment and interpretation of diagrams (Glaser, 1952; Miller and Folley J., 1952).

It has been demonstrated through controlled research that good trouble-shooters have skill in the use of logical elimination procedures and show more basic knowledge of their field than poor trouble-shooters (Saltz & Moore, 1953).

The know-how which a maintenance worker must have in order to perform satisfactorily depends on the level of maintenance at which he is working. The Armed Forces divide their maintenance function into three levels, namely:

a. organizatinal maintenance;

b. intermediate maintenance; and

c. depot.

At the first level, the malfunctioning "plug-in" unit is located and replaced. The defective unit passes to the second level, where it is further dismantled and analyzed. If the fault is within the range of this level, the unit is repaired and sent to the spare part stock. If the problem

exceeds the abilities of the intermediate maintenance level, it is passed on to the ultimate level, the depot. This system assures fast and accurate service while demanding a minimum of training time for the organizational and the intermediate maintenance levels (Foley, 1973).

The software provided at the different levels depends on the amount of training and experience the workers have. While the technicians in the depot usually have only technical order material, such as manuals and diagrams, the first and the second level work normally with more sophisticated aids.

Experimental evidence in the military has shown that improved maintenance and training through the use of well designed job performance aids results in significant savings (Foley et al., 1972). One study compared the performance of experienced technicians using "technical order" aids with high school subjects that received only 12 hours of training but used "fully proceduralized" aids . There were no substantial differences in performance between the two groups (Elliot and Joice, 1968).

The various types of software that are used as troubleshooting aids can be classified into the following four categories:

a. Fully Procedurelized Aids - These aids give step by step directions and informational support for all maintenance activities. The information is based on a

rigcrous maintenance task aralysis and includes (1) a picture cr drawing of the equipment location under consideration; (2) step by step directions of what to do; and (3) specific infcrmatien as to what the normal conditicns cf that location shculd be.

b. Procedures or Directions - Technical orders often prcvide step by step guidance for checkout procedures, but they do not give the complete information and they are cften not efficiently organized. The information is gathered in a less systematic way than under a, causing mcre errors and decreasing its usefulness.

c. Information Only - Information relevant to the equipment is presented in a non-systematic way. The technician has to pick out the data he needs and establish his cwn procedures.

d. Restructured Information - Job performance aids that prcvide improved presentation of symbolic and abstract infcrmation. They are less structured than fully proceduralized aids (Foley et al., 1972, p.18).

Maintenance in industry is done under different conditions than in the military. The organization is usually less structured and the software available is mostly technical information material (eg. diagrams, parts lists) provided by the manufacturer of the equipment. While it is known that fcr the Armed Forces the lack of fully prcceduralized aids make the job of maintenance technicians considerably

more difficult and requires higher investment in training, no such evidence is available for private industry.

For localizing a malfunction at any level of maintenance, be it in a military setting or in industrial enterprises, it seems necessary that a systematic procedure be employed (Palumbo, 1974). The two logical trouble-shooting methods being widely used are those based on failure rate and those done by logical elimination. When trouble-shooting based on failure rate data is employed, it is necessary to have detailed information about the failure rates of the individual components. The component with the largest failure rate is most likely to fail and is, therefore, checked first. The next check is on the second component in the list. The procedure is repeated until eventually the malfunctioning part is located. This method is effective for common failures, but very time consuming when components with low failure rates are involved.

When trouble-shooting by logical elimination, it is necessary to have information about the flow of the signal through the equipment. Once the chain is established, the half-split method can be employed for localizing the malfunction. The signal chain is interrupted in the midpoint between input and output and the arriving signal is checked. If it is within the tolerances, the fault is most likely in the second half of the chain. The second half is then divided again and the signal checked. Repetitious applica-

tion of this method leads to location of the fault with the least number of checks and consequently in the least time possible (Glanzer, 1958; Handbook, 1966; Miller et al., 1952; Zellitsch, 1954).

Trouble-Shooting Training Devices

Trouble-shooting is a task that can hardly be taught in a descriptive way. It must be taught in a "hands-on" manner (French, 1956). The type of equipment used for practicing the desired skills does not necessarily have to be the "real" equipment (Gagne, 1962). Economical, practical and psychological considerations should be taken into account when decisions about training hardware have to be made (Valverde, 1968).

The design criteria for training equipment should be derived from the results of a task analysis (Lawson, 1974, p.34; Miller, 1954). Mock-up designs should also be of a simple construction, which is an economic factor. They should provide facilities to insert malfunctions as well as being a faithful representation of the real equipment (French, 1956). This is true, but faithful representation becomes economically impractical with increasing sophistication of the original equipment. From the standpoint of transfer, it is often preferable to produce a mock-up that represents only the features of the real equipment that are important for the purpose of the training (Miller, 1954; Shriver et al., 1964; Valverde, 1968).

Task analysis can be seen in two ways (Chenzoff, 1964). The first method begins with the determination of systems functions and output criteria. Then the functions are allocated to men and machines and broken down into tasks and subtasks. The variables that are anticipated to affect task performance are analyzed and described. The data collected in a number of such analyses provide criteria for construction of a curriculum and for choosing or designing training equipment (Miller, 1956).

The second method begins with the decisions which have to be made about training and training equipment. It investigates the questions which need to be answered before these decisions can be made. These questions are not necessarily equal for different systems, thus each task analysis is tailored to gather the necessary information for each particular application. There are, however, generalized classes of decisions and data which will be relevant to most systems (Gustafson, Honsberger and Michelson, 1960).

Trouble-Shooting Performance Testing

The development of valid instruments to test performance in vocational and technical education has had much attention in recent years (Foley, 1967). Performance tests are often used to select, classify, train and assess human resources. If the measures are largely irrelevant to the jobs they are supposed to select personnel for, the wrong men would be given the job and valuable human resources would be disre-

garded (Wallace, 1965, p.1-10).

Considerable research effort has gone into the question of how closely achievement on paper and pencil tests and actual performance on a maintenance job are related. The results had shown the correlations to be generally very low (Brown et al., 1959; Shriver, 1960; Swanson, 1968, p.43).The low correlations are apparently caused by the fact that there is a difference between knowing about a job and actually being able to do it (Boyd and Shimberg, 1971, p.5).

Even though paper and pencil tests have been shown to be poor substitutes for actual job-task performance tests, their use still persists. The main reason for this is not the lack of understanding of the situation by teachers and supervisors, but the difficulties connected with development and administration of job-task performance tests (Foley, 1967, p.44). Some of these difficulties are: the increased cost for development, the increased time required for administration of a performance test, and the increased chance that vital information would be passed on to future examinees (Boyd et al., 1971; Harris & Mockie, 1962).

The inconveniences encountered with both job-task performance tests and paper and pencil tests have led to the development of symbolic equipment tests such as the Tab test and the MASTS test as well as peer and supervisor ratings (Foley, 1967). The correlations between symbolic tests and job performance are, generally, higher than with pure paper

and pencil tests. They are a compromise between job-task performance tests and paper and pencil tests. When well planned, they can be relatively valid measurement and training devices (Crowder, Morrison and Demaree, 1954; Grings, 1953; Saupe, 1954).

The development of job-task performance tests should be based upon the following information:

a. the critical aspects of the behavior to be measured in the test (through task analysis);

b. the type and nature of the test items to be used in measuring behavior;

c. the kind of apparatus or equipment needed; and

d. the criterion for the scoring of the items (Valverde, 1968).

The criteria applied for scoring a test depends upon the behavior which the test is supposed to measure. The factors that are often used as criteria for measuring trouble-shooting performance are:

a. time required to identify the symptoms of the problem;

b. time required to locate the trouble;

c. number of discrete steps taken in the trouble-locating activity;

d. number of erroneous replacements made; and

e. safety considerations (Boyd et al., 1971; Hansen, 1958).

After a performance test is developed it should be field tested. Sujects used in the trycut should be proficient in the field covered by the test. They should go through all the steps thus assessing the correctness of the directions. The trycut should debug the test and determine it's validity (Boyd, et al., 1971, p.37). Unfortunatly, researchers have given little atention to the assessment of the validity of job performance tests (Foley, 1974).

Summary

Maintenance is a critical aspect for both Armed Forces and industrial enterprises. The Armed Forces have invested considerable research efforts in the improvement of the maintenance operations. It has been found that a combination of rather conceptual training and the use of fully proceduralized job performance aids is most effective for the military environment.

However, there has been little evidence of serious research concerned with the application of these findings to the civilian industrial environment. In industry, the following conditions appear to be different:

a. the quantity of identical machinery and equipment is usually considerably lower;

b. the personnel turnover is less predictable;

c. industrial enterprises are concerned with maintaining production while the main concern of the Armed Forces is to be prepared for an emergency.

CHAPTER III

PROCEDURES

The organization of the major portion of this procedures chapter follows sequentially the several sub-problems presented in Chapter I.

Research Design

A randomized three group posttest research design was used for this study. A pretest was used to initially screen the applicants and to confirm the equality of the three randomized groups. Graphically, it is portrayed as follows:

```
                T1 --> M2, A
M1 --> R --> T2 --> M2, A
                C  --> M2
```

R....Randomization

T1...Training course on a specific system

T2...Training course on the concept of how machines work

C....Control group receiving orientation but no training

M1...Pretest for selection of trainees and control of equivalency

M2...Trouble-shooting performance test

A....Attitude inventory

Research Hypotheses

The following hypotheses were prepared in response to the ninth sub-problem and the review of the literature:

1) There will be no significant difference (.05 level) in the trouble-shooting performance on equipment treated in the specific training between trainees that received conceptual training and trainees that received specific training.

2) Trainees with a conceptual knowledge will perform significantly better (.05 level) on unfamiliar equipment than trainees with a specific knowledge.

3) There will be no significant difference (.05 level) in the attitude toward the job between trainees that received the specific training and those that received the conceptual training.

Population and Sampling

The target population is potential maintenance technicians-journymen in mechanics and electricians occupations in Northwest Ohio.

The experimental subjects for the two samples were students at Bowling Green State University (BGSU) and citizens in Northwest Ohio with no post high school technical course-work. A pretest, the Test of Mechanical Comprehension, Form T by George K. Bennett, was given to all the subjects that applied for the salaried training positions. Thirty-nine

subjects that scored in the middle range (41 to 62) were selected and randomly divided into three groups. There were 15 subjects in each treatment group and nine subjects in the control group.

Measurement Strategies and Devices

Sub-problems 1,2,3 and 4 are referred to for the procedural development of the measurement strategies and devices.

Restatement of sub-problem 1: To identify principal components of production machines through a logical analysis of their systems.

This problem was resolved by logical inference rather than with statistical procedures. The following is the logical analysis used in this study.

Any sophisticated machine can be described as receiving material as an input and, using energy, processing the material.

The process of transformation is accomplished by the combination of a series of components that can be classified into: a) energy converters; b) power converters; c) power transmissions; and d) control elements (Palumbo, 1974).

An energy converter transforms energy into power, depending on the particular need. For example, in a thermo-electrical power plant the potencial energy in coal or fuel is transformed into heat energy, which is converted into electrical power.

Power exists in the form of electrical, mechanical and fluid power; a power converter changes only it's form. As for example, an electrical motor transforms electrical power into mechanical power. When coupled to a pump, this mechanical power is converted into fluid power.

The role of a power transmission line is the transport of power. A copper wire can be the medium to transport electrical power from the producer to the consumer, and the drive shaft transports mechanical power from the engine to the differential gear. The control elements are probably the most diversified and sophisticated parts of a machine. Their range extends from final control elements, such as switches and valves, to primary sensors (e.g. thermocells, pressure sensors, encoders) and decision making elements (controllers).

Restatement of sub-problem 2: To develop an arrangement of components into a simulator that represents a typical system found in production machines.

From the preceding discussion it can be seen that any machine can be represented by a combination of relatively simple building blocks. These blocks can be simulated with standard lab equipment available at BGSU.

This arrangement of lab equipment can be referred to as a simulator. The simulator should satisfy the following criteria:

a. Trainees with no previous technical background, ar-

ter receiving a short instruction should be able to perform tasks of trouble-shooting on it.

b. It must include electrical, mechanical and fluid components.

c. It must include energy converters, power converters, power transmissions and control elements.

d. There should be facilities to easily inject malfunctions on different points in the system.

e. The individual elements must be easily accessible and observable.

f. There must be easily accessible checkpoints throughout the system.

g. The necessary measuring equipment should be of a simple nature.

A machine for press fitting bearings was selected to be simulated. The above criteria were applied for fabrication and evaluation of the simulator. Appendix E shows a pictorial drawing of the simulated machine, the schematic diagram and a photograph of the apparatus.

Restatement of sub-problem 3: To develop a test that measures trouble-shooting performance using the simulator.

For the present study, the factors defining trouble-shooting performance were: 1) whether the malfunction was located or not within a time limit of five minutes; and 2) the time needed for localizing the malfunction. The number of checks made was not recorded since the procedure employed

by the trainees was not a consideration of the study.

Each trainee was required to trouble-shoot four times on the equipment. Two malfunctions were within the components covered in the specific training. The remaining two were in any one of the other components of the simulator. For any trouble-shooting performance task, the simulator was prepared with only one malfunction.

If the trainee could not localize a malfunction, the researcher indicated the malfunctioning part, explained why it caused the problem and repaired the simulator.

Restatement of sub-problem 4: To develop a method for evaluating the attitudes of the trainees toward the job.

The attitudes of the trainees toward their job was assessed through questions around the following points:

a. attitudes towards the job (of a maintenance technician);

b. attitudes towards their training ;

c. attitudes towards the task of trouble-shooting ; and

d. attitudes towards the equipment.

The questionnaire can be found in Appendix J.

Treatment

Restatement of sub-problem 5: To develop a short training course about the concepts that underly the function of machines (conceptual approach) and the systematic procedures used for trouble-shooting.

A self instructional module (SIM) was chosen as the instructional method. The analysis that led to this decision is illustrated in the decision matrix included in Appendix C.

A SIM of the scope of approximately one to two hours was developed. The content was oriented on the "EPIC Philosophy" (Palumbo 1974). The SIM can be found in Appendix B.

Restatement of sub-problem 6: To develop a short training course about one particular part of the system (specific approach) and the systematic procedures used for trouble-shooting.

The material was of the same type and scope as the conceptual course. The content treated fluid systems, gave a brief introduction into principles (pressure, flow, etc.) and described components, their function and interaction. The SIM is included in Appendix A.

A panel of experts reviewed both SIMs for their correctness and equivalency. The panel confirmed the equivalency of the two SIMs and their representativeness for the two approaches to trouble-shooting training. The rating sheet used for this evaluation is included in Appendix D.

The subjects were given posttests to assess their content mastery of the respective course contents.

Analysis of the Data

The data collected on the performance test was organized into three scores and two sub-scores as shown in the follow-

ing cells:

	sub-score a (familiar)	sub-score b (unfamiliar)
Score 1	success	success
Score 2	time	time
Score 3	success+time	success+time

Score 1 was the number of times the trainee succeeded in localizing a malfunction.

Score 2 represented the time needed for trouble-shooting. When a malfunction was located within one minute, the trainee scored five points. Respectively, wher the trainee needed five minutes or did not localize the malfunction within the time limit, his score was one.

Score 3 was found by multiplying score 1 by ten and adding score 2.

Each of the three scores had two sub-scores. Sub-score a was the result of the two performance tasks on equipment treated in the specific training program. The remaining trouble-shooting performance scores were combined in sub-score b.

For testing the first and second hypotheses, two "t" tests were applied comparing the 3a and 3b mean scores of the two groups.

The third hypothesis was tested by a "t" test comparing the mean scores on six groups of questions on the attitude inventory. The groups were organized as stated in the section on measurement strategies and devices in this chapter.

Sequence of Events

The sequence of events is presented in the form of a list of the Program Evaluation and Review Technique (PERT) events together with a PERT flowchart. Both can be found in Appendix I.

CHAPTER IV

ANALYSIS AND DISCUSSION OF THE DATA

Pretest

One purpose of the aptitude pretest was to confirm the assumed equality of the three randomized groups by comparing their mean scores on the Bennett Test for Mechanical Comprehension. There was no significant difference ($p>.05$) between the randomly selected treatment and control groups. Table 1 shows the summarized data.

Table 1
Two tailed "t" test of means of the scores of the three groups (specific, conceptual and control) on the Test for Mechanical Comprehension by G. Bennett

Group	N	SumX	Xmean	SD
Specific	15	816	54.4	3.92
Conceptual	15	810	54.0	3.68
Control	9	457	50.1	9.54

Specific vs Conceptual: df=28, t=.288, p>.2 (not significant at the .05 level)
Specific+Conceptual vs Control: df=37, t=1.83, p>.1 (not significant at the .05 level)

Restatement of Hypothesis I:

There will be no significant difference (.05 level) in the trouble-shooting performance on equipment treated in the specific training between trainees that received conceptual training and trainees that received specific training.

Trouble-shooting performance was defined as the trainees success in localizing a malfunction and the time needed to complete the task. The maximum time allowed for each trouble-shooting task was five minutes.

No significant difference ($t=.104$, $p>.2$) was found in the trouble-shooting performance of the two treatment groups. Therefore hypothesis I is accepted.

The two treatment groups performed significantly better ($t=3.48$, $p<.001$) than the control group. Table 2 presents a summary of the data.

Restatement of Hypothesis II:

Trainees with conceptual knowledge will perform significantly better (.05 level) on unfamiliar equipment than trainees with specific knowledge.

No significant difference ($t=.05$, $p>.2$) could be found in the performance of the two groups on equipment not treated in the specific training. Hypothesis II had to be rejected.

Both treatment groups performed significantly better ($t=4.75$, $p<.001$) than the control group.

The pertinent data is summarized in Table 3.

Table 2

Two tailed "t" tests of means of the scores of the three groups (specific, conceptual and control) on equipment treated in the specific training (subscore a).

Score 1 - successfully completed trouble-shooting tasks

Group	N	SumX	Xmean	SD
Specific	15	14	.93	.80
Conceptual	15	13	.87	.74
Control	9	3	.33	.50

Specific vs Conceptual: df=28, t=.237, p>.2 (not significant at the .05 level)

Specific+Conceptual vs Control: df=37, t=3.415, p<.001 (significant at the .001 level)

Score 2 - time needed for trouble-shooting

Group	N	SumX	Xmean	SD
Specific	15	55	3.67	2.02
Conceptual	15	48	3.20	1.65
Control	9	21	2.33	.71

Specific vs Conceptual: df=28, t=.691, p>.2 (not significant at the .05 level)

Specific+Conceptual vsControl: df=37, t=3.068, p<.01 (significant at the .01 level)

Score 3 - trouble-shooting performance (score 1x10+score2)

Group	N	SumX	Xmean	SD
Specific	15	183	12.2	8.78
Conceptual	15	178	11.87	8.84
Control	9	50	5.55	5.36

Specific vs Conceptual: df=28, t=.014, p>.2 (not significant at the .05 level)

Specific+Conceptual vs Control: df=37, t=3.482, p<.001 (significant at the .001 level)

Table 3

One tailed "t" test of means of the scores of the three groups (specific, conceptual and control) on equipment not treated in the specific training (subscore b)

Score 1 - successfully completed trouble-shooting tasks

Group	N	SumX	Xmean	SD
Specific	15	16	1.07	.59
Conceptual	15	16	1.07	.70
Control	9	4	.44	.52

Specific vs Conceptual: df=28, t=.0, p>.2 (not significant at the .05 level)

Specific+Conceptual vs Control: df=37, t=4.111, p<.001 (significant at the .001 level)

Score 2 - time needed for trouble-shooting

Group	N	SumX	Xmean	SD
Specific	15	61	4.07	1.70
Conceptual	15	59	3.93	1.53
Control	9	19	2.11	.33

Specific vs Conceptual: df=28, t=.225, p>.2 (not significant at the .05 level)

Specific+Conceptual vs Control: df=37, t=6.122, p<.001 (significant at the .001 level)

Score 3 - trouble-shooting performance (score 1x10+score 2)

Group	N	SumX	Xmean	SD
Specific	15	221	14.73	7.13
Conceptual	15	219	14.60	8.14
Control	9	59	6.51	.40

Specific vs Conceptual: df=28, t=.05, p>.2 (not significant at the .05 level)

Specific+Conceptual vs Control: df=37, t=4.75, p<.001 (significant at the .001 level)

Restatement of Hypothesis III

There will be no significant difference (.05 level) in the attitude toward the job between trainees that received the specific training and those that received the conceptual training.

No significant differences were found between the two groups in their responses to the attitude inventory. Hypothesis III is accepted.

Both groups considered the simulator as a good representation of a real machine. The quality and relevancy to the task of trouble-shooting of the SIMs was confirmed by both groups. Table 4 presents the data organized according to the six components of the attitude inventory. The attitude inventory is included in Appendix K.

Table 4
Two tailed "t" tests of means of the attitude sub-scores of the two treatment groups

Quality and representativeness of a real machine by the simulator

Group	N	max possible	Xmean	SD
Specific	15	18	14.	1.69
Conceptual	12	18	15.5	1.93

df=25, t=2.025, p>.05 (not significant at the .05 level)

Quality of the SIM and interest in the subject presented by the SIM

Group	N	max possible	Xmean	SD
Specific	15	24	17.2	3.84
Conceptual	15	24	17.46	3.50

df=28, t=.199, p>.2 (not significant at the .05 level)

Relevancy of the content of the SIM to the task of trouble-shooting

Group	N	max possible	Xmean	SD
Specific	15	6	4.67	1.80
Conceptual	15	6	4.40	1.89

df=28, t=.397, p>.2 (not significant at the .05 level)

Table 4 (Continuation)

Interest in the task of trouble-shooting

Group	N	max possible	Xmean	SD
Specific	13	18	12.3	3.81
Conceptual	15	18	12.8	2.37

df=26, t=.425, p>.2 (not significant at the .05 level)

Trouble-shooting is an easy task

Group	N	max possible	Xmean	SD
Specific	15	6	1.87	1.19
Conceptual	15	6	2.27	1.80

df=28, t=.757, p>.2 (not significant at the .05 level)

Need for detailed knowledge of a machine (simulator) for effective trouble-shooting

Group	N	max possible	Xmean	SD
Specific	15	6	4.27	1.67
Conceptual	15	6	3.60	1.55

df=28, t=1.134, p>.2 (not significant at the .05 level)

Summary

In summary, the data indicates that both training methods were effective. This is demonstrated by: a) the significantly higher performance of the treatment groups as compared to the control group; and b) the trainees in both treatment groups indicated that the training they received was relevant to and helpful for the trouble-shooting tasks.

While both the specific and conceptual training programs caused significant gains in trouble-shooting performance, neither training method proved superior. There was no significant difference in the performance between the specifically and conceptually trained groups.

CHAPTER V

SUMMARY AND CONCLUSIONS

Restatement of the purpose of the study

This study was concerned with the effect of conceptual versus specific (traditional) training on the trouble-shooting performance of maintenance technicians.

To accomplish this undertaking, nine sub-problems were pursued in depth. They were:

1. To identify the principal components of production machines through a logical analysis of their systems.
2. To develop an arrangement of components into a simulator that represents a typical system found in production machines.
3. To develop a test that measures trouble-shooting performance, using the simulator.
4. To develop a method for evaluating the attitudes of trainees toward the job.
5. To develop a short training course on the concepts that underly the function of machines (conceptual approach) and the systematic procedures used for trouble-shooting.
6. To develop a short training course about one particular part of the simulated system (specific approach) and the systematic procedures used for trouble-shooting.

7. To select trainees for the two experimental groups and the control group.

8. To execute the experiment.

9. To collect and analyze the data so as to evaluate the effectiveness of the two approaches to training for the task of trouble-shooting.

Conclusions

Research outcomes resulting from each of these pursuits have been presented in the preceding chapter.

The analysis of the data indicates that neither approach (specific versus conceptual) to training maintenance technicians was superior. However, both treatment groups performed significantly better than the control group. Within both the specific and conceptual training programs, trainees received instruction on systematic trouble-shooting procedures. It could be speculated that these trouble-shooting directions were more important than the bulk of the information contained in the SIMs.

Casual observations by the researcher during the performance test added to this inference. Subjects that had no training (control group), generally, did not follow any systematic procedure of trouble-shooting. They opened and closed valves and switches at random and were rather helpless in front of the simulator. On the other hand, subjects that received training through both the specific and conceptual methods tended to follow a more organized procedure.

This is consistent with findings of several studies by the Air Force Human Resources Laboratory. They emphasize the importance of giving directly applicable information (job performance aids) over providing a broad technical background for training maintenance technicians (Elliot et al., 1968; Foley et al., 1972; Saltz et al., 1953). Obviously, the economical feasibility of producing trouble-shooting job performance aids for industrial applications is unknown.

One could raise the question that the treatment was too short to render significant results. This may well be the case. Both treatment groups received only theoretical instruction without hands-on experiences. This could have caused problems of transfer of training.

Learning psychologists stress the importance of establishing a "learning chain", i.e. a learner should master all necessary prerequisites before advancing to higher level tasks. Since trouble-shooting is essentially problem solving, and, therefore, cognitive higher level behavior, many prerequisites and a certain intellectual maturity of the trainee are required. Does this mean that maintenance technicians have to reach a high intellectual level (through either specific or conceptual training) to become effective trouble-shooters? The researcher believes that this would be the case if a technician had no experience and/or job performance aids.

The findings of this study together with the experiences and observations made by the researcher are reflected in the following recommendations for further research:

1. A study of the economic feasibility of developing job performance aids for sophisticated equipment in industrial enterprises.
2. A repetition of the present study with a treatment of major scope (minimum 50 hours) that includes hands-on experiences.
3. To develop or select and validate a test battery that measures trouble-shooting aptitude. This test battery could be used to select trainees for maintenance courses. It would also give useful information for designing courses to improve trouble-shooting abilities.

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APPENDIX A

Self Instructional Module

Introduction to Fluid Systems

Introduction to Fluid Systems

General Goals: To introduce the trainee to the principles underlying the function of pneumatic and hydraulic systems, i.e. pressure, flow, and power.

To describe the function and the use of basic components of fluid systems.

To indicate procedures used for trouble-shooting fluid circuits.

Performance objectives: After receiving this instruction the trainee should be able to:

1) Define pressure and identify the instruments used to measure it.
2) Apply the pressure principle to a simple force problem and calculate the answer.
3) Define flow and identify at least one instrument used to measure it.
4) Given pressure and flow, calculate the horsepower of a fluid circuit.
5) Identify the graphic symbols of: pumps, cylinders, common valves, and accumulators.
6) Using a circuit diagram, indicate the steps to take for localizing malfunctions within a fluid system.

Note: Principles that apply to both pneumatic and hydraulic systems are treated generally. Pneumatic magnitudes and units are used for specific examples.

1.8

The content of this instruction is arranged in form of a self instructional module (SIM). Information is presented to you in small units. At the end of each frame or during the text you will be asked questions about material previously presented. You will find the correct answers on the side of the page.

Example:	
Bowling Green State University is located in _____.	Ohio
The Technology Building is located in the __(northern or southern)____ part of the campus.	northern

It is recommended to conceal the answers while you are working with the material. After you put down your own answer, you can check its correctness by comparing it with the given answer.

Sometimes you will use words in your response that are different from the ones given as the correct response. As long as the meaning is the same, your answer can be considered correct. If you cannot answer a question correctly, go back and reread the information leading to the question. If after careful rereading of the information you still have problems understanding the information ask the instructor for help.

Frame 1

What is fluid power?

Although fluid power has been known for many centuries, its extensive use has only recently begun.

The water wheel is one of the oldest machines used by man. It uses the power of flowing water to accomplish work. Modern fluid power is defined as power transmitted and controlled through the use of pressurized fluids. The pressurized fluid is oil in most hydraulic systems and air in most pneumatic systems.

Fluid power systems use pressurized _____ to transmit power.	fluid
The pressurized fluid is normally _____ in hydraulic systems and _____ in pneumatic systems.	oil air

50

Frame 2

Why fluid power is used:

Fluid power is used extensively because of its flexibility and versatility. It can be unyielding as steel yet completely flexible. It will change its shape to fit the body that resists its thrust and can be divided into parts. Its flow can be controlled by valves and it can be stalled and restarted without creating problems in the system.

Fluid power is used extensively because of its _____. | versatility, flexibility

Frame 3

Where fluid power is used:

There is scarcely an industry that does not incorporate pneumatic or hydraulic applications either in its manufacturing process or in its product.

Familiar examples of the use of fluid power are the barber chair and the service station grease rack.

The barber uses a small pump to force oil to a cylinder that raises and lowers the chair.

The gas station service man turns a valve that allows compressed air to enter a cylinder that raises your car.

Generally, any operation that requires pushing, lifting, clamping, pressing, etc., can be conveniently handled with fluid power. It can also be used to produce rotary motion, such as an airdrill, but straight line motion produced by cylinders is most common.

Fluid power is conveniently applied for producing ___ ____ straight line movements, such as pulling and lifting.

52

Frame 4

Pneumatics versus Hydraulics:

A fluid power system is called a hydraulic system when the fluid is a liquid, normally oil.

The term "pneumatics" is used when gas, normally air, is used as the fluid.

Both types of fluid have advantages and shortcomings, depending on the specific application.

If a piston has to be moved at a constant speed or stopped at a specific place with accuracy, oil is the most convenient fluid. Oil cannot be compressed. This guarantees an exact proportional movement.

On the other hand, if accuracy is not as important as elasticity, cost and speed, air offers advantages over liquids.

The main difference is that gases (air) are compressible, while liquids (oil) are not.

The basic principles apply for both types of fluid, liquids and gases.

Pneumatics is the term used when the fluid is a _____. gas

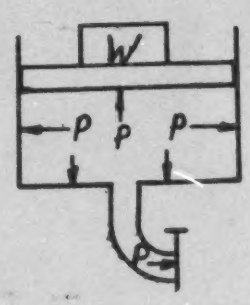
Hydraulic deals with __(compressible or non-compressible)__ fluids. non-compressible

Frame 5

Pascals Law:

Pascals Law is the base of operation of many fluid power devices.

Pressure applied anywhere to a confined fluid is transmitted without loss and acts at right angles to every part in the containing vessel.



If a cylinder is filled with fluid and a weight placed on a piston, pressure is created in the fluid. The pressure acts upon the enclosing surfaces, (the walls of the cylinder and the pipe, the shut-off valve and the piston, etc.)

The pressure created in the confined fluid depends upon the size or area of the piston and the force applied to it. The pressure increases when the force increases or/and when the area of the piston decreases.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}, \quad \text{pound per sq. in.} = \frac{\text{pounds}}{\text{sq.in.}} = \text{psi}$$

Pascals Law states: The pressure within a confined fluid is __(equal or not equal)__ in any part. equal

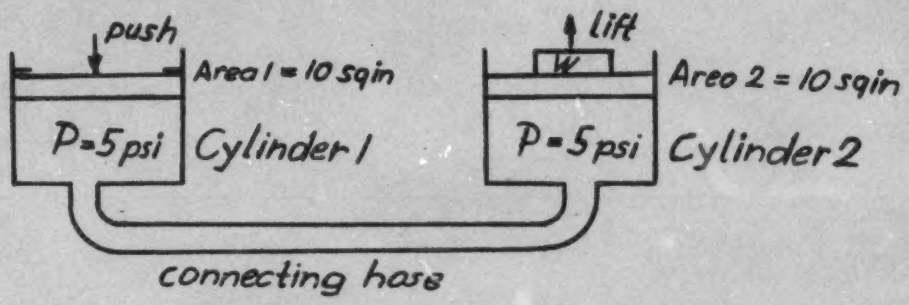
The pressure created by a piston depends on the force applied and on the _____ of the piston. area

54

Frame 6

Hydraulic Jack:

Hydraulic jacks work on the principles explained in the preceding frame.



Two cylinders are connected by a hose so the fluid can pass freely from one cylinder to the other.

Suppose the piston of cylinder 1 is in its upward position.

If a weight of 50 pounds is placed on piston 2, a pressure of $P = \frac{\text{Force}}{\text{Area}} = \frac{50}{10} = 5$ psi (pounds per squre inch) is created in the fluid.

To lift piston 2 you can push piston 1 down with a force of 50 pounds. (You would really have to apply just a little more than 50 pounds to overcome inertia and friction of the fluid.)

If the areas of the two pistons are equal, the two forces (push and lift) are _____ _____. also equal

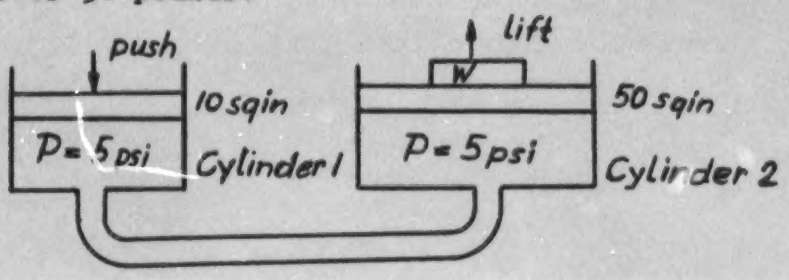
55

Frame 7

Hydraulic Jack (continuing)

What if the two cylinders are of unequal size?

Let the area of cylinder 2 be 50 sq. in. instead of 10 sq. in. We still push on cylinder 1 with the same force of 50 pounds.



The pressure in the system is therefore again $P = \frac{50}{10} = 5$ psi.

For cylinder 2, $P = \frac{\text{lift force}}{\text{area}}$,

since the pressure in cylinder 2 is also 5 psi and the area is known to be 50 sq. in., the lift force can be calculated.

Lift force = P x area or 5 x 50 or 250 pounds

Beginners are sometimes bothered by the idea that a small push on one piston can produce a large lifting force in the other. Remember that the lever of a hydraulic jack has to be pushed many times to lift the car a small distance.

A weight lifter can lift a weight of 300 pounds in less than a second. Using a hydraulic jack you can lift the same weight, but it takes you longer.

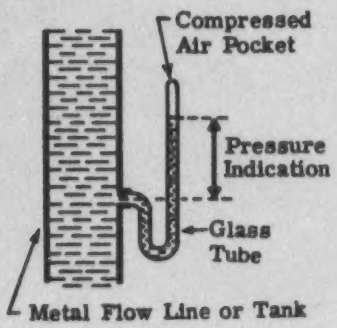
If 100 psi is applied to a 10 sq. in. piston, a weight of _____ pounds can be lifted.

1000

Frame 8

The measurement of pressure:

The manometer is the simplest instrument for measuring pressure.



BASIC MANOMETER

It is a glass tube containing a gas or a liquid. The tube can be connected to the point of pressure measurement in a variety of ways. The drawing shows the basic construction. The pressure of the fluid in the tank or line forces fluid into the glass tube, where it lifts a column of liquid (such as mercury).

The pressure is determined by measuring the difference in height, as shown in the diagram. Multiplying this distance by a calibration factor converts the distance to pressure in pounds per square inch (psi) or any other desired unit of pressure measurement.

The difference in height of the liquid in the glass tube is caused by the _____ of the fluid in the flow line or tank.

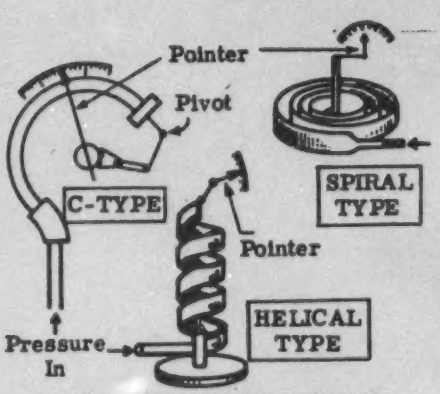
pressure

Frame 9

The measurement of pressure (continuing)

Other commonly used devices for pressure measurement are bourdon, diaphragm and bellows gages. They compare the force created by the pressure with a spring of known value.

The bourdon tube is probably the most popular of the gages described here.



TYPES OF BOURDON GAGES

It consists of a tube bent into the shape of a portion of a circle, a spiral or a helix. One end of the tube is closed and free to move.

The other end is connected to the point at which pressure is to be measured.

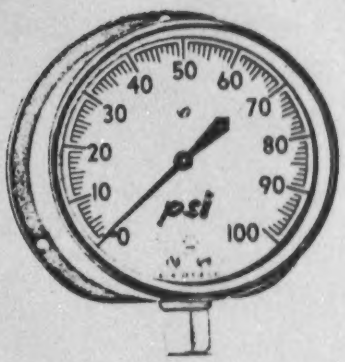
The pressurized fluid inside the tube tends to straighten the curvature. This moves the free end of the tube which, in turn, drives a pointer up a scale which is graduated in terms of the desired pressure units.

The greater the pressure of the fluid inside the bourdon tube, the more the tube tends to _____. straighten

Frame 10

The measurement of pressure (continuing)

Pressure gages are very useful for obtaining information about the state of the fluid circuit.



For example, if a cylinder does not work you can check the pressure in the supply line to the cylinder. If the pressure gage indicates 0 psi, the cylinder does not receive the fluid power it needs to do its job.

You would have to look for the trouble in the devices that supply the fluid to the cylinder (e.g. valves, lines, pumps)

The symbol for pressure gages used in schematic diagrams of fluid circuits is:

Pressure gages are usually calibrated in _____. psi

If a pressure gage measures 0 psi in a device, this device (holds or holds no) power. holds no

Frame 11

Flow

Pressure alone does not produce work in a fluid system. For example, if a tank is filled with air under a pressure of 500 psi, which is considerable, and all the outlets are closed, the compressed air does not accomplish work. The grease rack in the service station cannot raise your car if the airsupply line is closed. When opening the valve, air is allowed to flow into the cylinder and the car is lifted. The speed with which the car is lifted depends on the rate of flow and the cylinder area. The rate of flow, in turn, depends on the amount of air entering the cylinder per unit of time, (i.e., the rate of flow is proportional to the amount of air entering the cylinder).

The flow rate is a measure of the volume of fluid passing a point at a given time. It is usually measured in cubic feet per minute (ft^3/min) in pneumatics and gallons per minute (g/min) in hydraulics.

If the rate of flow of a system increases, the speed of the output (e.g., lifting a car) _____. | increases

In pneumatic systems, flow rate is measured in _____ ____ | cubic feet

per _____. | minute

Frame 12

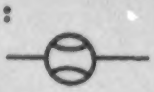
Flow measurement:

There are many types of devices that serve as flow meters. A relatively simple yet accurate instrument is the rotameter.

It consists of a conical tube of glass containing a steel ball. When fluid enters the rotameter through the inlet, the ball is pushed up allowing the fluid to pass by. The greater the rate of flow, the higher the ball is pushed up.

The position of the ball on the scale indicates the rate of flow.

In schematic diagrams flow meters are shown as:



In a rotameter, the higher the ball is pushed up, the (higher or lower) is the flow rate. higher

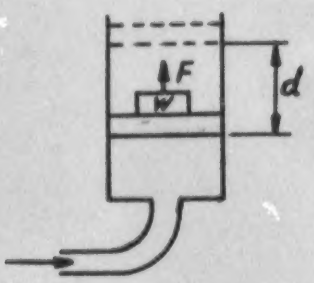
If the ball is in its extreme downward position, there is no flow in the circuit and work (can or cannot) be done in the circuit. cannot

61

Frame 13

Work:

Work is done whenever a force is applied through a distance.



If a piston carrying a weight W is raised the distance d work has been done in the amount:

Work = Weight x Distance

Instead of carrying a weight, the piston could also apply a force F against an obstacle.

Work would then be done in the amount:

Work = Force x Distance or W = F x d

If the piston raises a weight of 100 pounds a distance of 2 feet, work has been done in the amount W = F x d or 100 x 2 or 200 ft lb (foot pound). The same principles apply for all cylinders, regardless of the direction in which they move.

A piston pushing with a force of 1000 pounds and a stroke (distance) of 1.5 ft. does work in the amount of _____ ftlb. 1500

Frame 14

Power:

Power is the rate or speed of doing work.

Looking at the example in the previous frame, if the piston needs one minute to push the 1000 pounds 1.5 ft, it develops less power than when it does the same work in one second.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} \quad \text{or} \quad \frac{\text{Force x distance}}{\text{Time}}$$

In fluid systems the distance is analogous to flow and the force to pressure. Flow rate is therefore analogous to distance divided time.

Power = Pressure x Flow rate

For convenience of comparison, we will transform to Horse Power:

$$\text{Power} = .0044 \frac{\text{ft}^3}{\text{min}} \times \text{psi} \qquad \text{pneumatics}$$

and

$$\text{Power} = .000583 \frac{\text{gallon}}{\text{min}} \times \text{psi} \qquad \text{hydraulics}$$

Example:

The grease rack has the following parameters:

Flow rate = 5 ft^3/min
Pressure = 100 psi

The power of the pneumatic cylinder is:

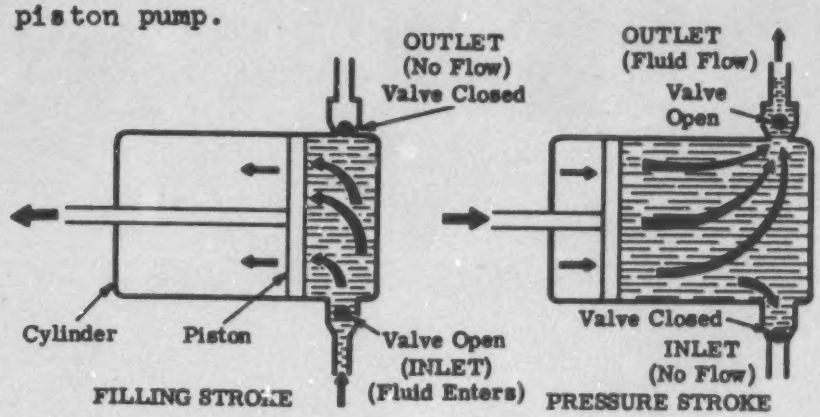
Power = .0044 x 5 x 100 = _____ 2.2 HP

Frame 15

Pumps:

Pumps are devices that create pressure and flow, (i.e. fluid power, in fluid systems and circuits).

A basic type of pump used frequently in pneumatic systems is the piston pump.



The piston pump has a two stroke operating cycle. During the filling stroke, the face of the piston moves away from the outlet end. The pressure in the outlet pipe is higher than that in the cylinder, and the outlet ball valve is forced downward, thus closing the opening. The pressure in the cylinder is also lower than that in the inlet pipe, and the inlet ball valve is forced upward. This allows liquid from the inlet pipe to enter the cylinder.

Frame 15 (continuing)

When the piston reaches its extreme left position, it reverses its direction of travel and the pressure in the cylinder increases because of the mechanical force that is pushing the piston.

The inlet ball valve is forced down, closing the inlet pipe and preventing fluid from flowing out in that direction. At the same time, the outlet ball valve is forced upward, and the fluid is forced into the outlet pipe.

Valves which permit flow in only one direction, as in the piston pump, are known as "check" valves.

When the piston moves away from the outlet end, the pressure in the cylinder _____, forcing the inlet valve to open. decreases

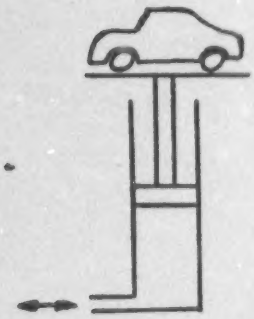
During the pressure stroke, the inlet valve is _____. closed

The schematic symbol of a pump is:

Frame 16

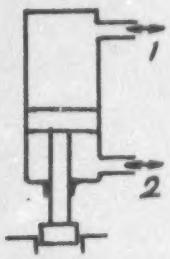
Cylinders:

A cylinder is a device that has a tube, a movable piston with a rod connected to it and caps to seal the ends. In addition, it has one or two connections for fluid lines. These connections are called ports.



Cylinders with one port are used, for example, as grease racks in gas stations. Pneumatic power is needed for lifting only. The lowering is done by simply allowing the air in the lower part of the cylinder to escape and the weight of the car brings it down.

Other applications need cylinders with two ports, as for example in a stamping press.



Fluid enters the cylinder through port 1 and pushes the piston down. When the stamping operation is completed, port 1 is connected to the exhaust and fluid entering the cylinder through port 2 lifts the piston.

A critical aspect of cylinders is the sealing problem. When the seals are old, worn out or otherwise damaged, fluid escapes and the cylinder looses force.

Frame 16 (continuing)

A cylinder consists basically of a tube with two caps on the ends and a movable _____. | piston

Care should be taken to avoid leakage in cylinders. A leaking cylinder looses _____. | force

Frame 17

Cylinders - calculations:

To find the force a cylinder can apply, it is necessary to know the area of the piston. If only the inside diameter or bore of the piston is known, the area can be calculated by the formula:

$$A = \left(\frac{d}{2}\right)^2 \times \pi \qquad \text{or } A = .785 \times d^2$$

where A = area in sq. in.

d = diameter in inches

$\pi = 3.14$

A cylinder with a "bore" (diameter) of 6 inches has an area of:

$$A = \left(\frac{6}{2}\right)^2 \times \pi =$$

$$3^2 \times \pi = 28.26 \text{ sq. in.}$$

The force of the cylinder can then be calculated by multiplying the pressure of the fluid entering the piston by the area of the piston.

$$F = A \times P$$

where F = force in lb

A = area in sq. in.

P = pressure in psi

To calculate the speed with which a piston will travel, the flow rate and the area of the piston must be known.

$$\text{Speed} = \frac{\text{flow rate}}{\text{area}}$$

Frame 17 (continuing)

The larger the piston area, the slower will the piston travel.

If the flow rate increases (i.e. more fluid enters the cylinder in the unit of time), the speed of the piston _____.

increases

Knowing the piston speed, the time needed to complete the stroke can be calculated (stroke = distance between full in and full out)

$$\text{Time} = \frac{\text{stroke}}{\text{speed}}$$

The faster the piston travels the __(more or less)__ time will it take to complete its stroke.

less

Example:

A cylinder has a stroke of 1 ft. and an area of 25 sq. in. (or .174 sq. ft.). The flow rate is 1.74 ft^3/min.

To find the time the piston needs to complete the stroke, we have to use the area in sq. ft., since the flowrate is given in ft^3/min.

The speed is

$$\text{Speed} = \frac{\text{flowrate}}{\text{area}} = \frac{1.74}{.174} = 10 \text{ ft/min.}$$

or the time the piston needs to travel 1 ft. is

$$\text{Time} = \frac{\text{stroke}}{\text{speed}} = \frac{1 \text{ ft}}{10 \text{ ft/min}} = .1 \text{ min.} = 6 \text{ sec.}$$

70

Frame 17 (continuing)

From the preceding discussion we can summarize:

The force of a cylinder is directly proportional to pressure and _(dependent or independent)_ of flow. independent

Speed or rate of travel depends upon the flowrate and is _(dependent or independent)_ of pressure. independent

Frame 17 (continuing)

If a cylinder has a bore of 3 inches (.25 ft) and a 2 ft. stroke, and the compressor delivers a flow of .5 ft^3/min at a pressure of P = 100 psi, calculate:

The area of the piston is

$A = .785 \times d^2 =$ _____ sq. in. | 7.065 or rounded 7

or

$A = .785 \times d^2 =$ _____ sq. ft. | .049 or rounded .05

For calculating the force of the cylinder the area in

__(sq. in. or sq. ft.)__ has to be used, because the pressure is given in pounds per square inch (psi). | sq. in.

The force of the cylinder is

F = _____ x _____ = _____ lb | P, A, 700

The speed of travel of the piston is

$$\text{Speed} = \frac{\text{flowrate}}{\text{area}}$$

This time the area in __(sq. in. or sq. ft.)__ must be employed. | sq. ft.

Speed = _____ ft/min | 10

And finally, the time needed to complete the stroke is

$$\text{Time} = \frac{\text{stroke}}{\text{speed}} =$$ _____ min. | .2 min or 12 seconds

72

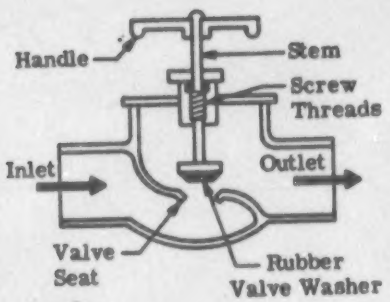
Frame 18

Valves:

Valves are devices that control flow direction, pressure or flow rate. Valves direct fluid at the right pressure and under suitable flow rates to the proper place, to produce correct operation of the work units.

There are many types of valves that are used in industrial applications.

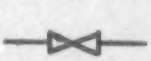
The type of valve you are most familiar with is the type that controls the flow of water in a wash basin or sink.



As the handle is turned in one direction or the other, the screw threads in the stem raise or lower the rubber valve washer that is mounted on the end of the stem. Thus, the movement of the washer towards or away from the valve seat increases or decreases the size of the opening through which the water can flow, and this controls the flow of water quite effectively.

This valve, or variations of it, is used for any kind of fluid as shut-off and flow rate regulating valves.

The symbols used in schematic diagrams are:

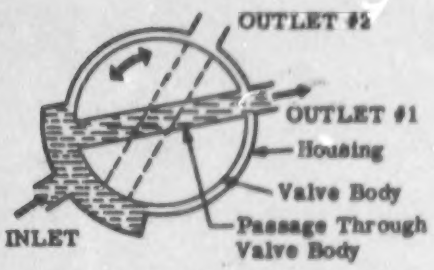
shut-off valve  restriction valve (flow control)

As the rubber washer is raised, the rate of flow _____. increases

Frame 19

Valves (continuing)

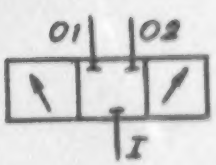
Other types of valves are used to direct the fluid flow from one pipe to one or more other pipes.



SELECTOR VALVE

The selector valve shown in the drawing has one inlet and two outlets. According to the position of the valve body either outlet can be connected to the inlet, or both outlets can be blocked.

The schematic symbol for this valve shows three boxes indicating the three possible positions of the valve.



The connections are only shown once to avoid confusion.

Left box: The arrow indicates passage from I (inlet) to 01 (outlet 1).

Center box: No arrow indicates that both outlets are blocked.

Right box: The arrow indicates passage from I to 02.

Frame 19 (continuing)

Another example is the valve that would be used for the stamping press described earlier.

This valve has two positions, symbolized by the two boxes in the schematic symbol. In one position the supply is connected to port 1; port 2 is exhausted. In the other position the arrangement is inverted. The supply is connected to port 2; port 1 is exhausted.

The valve described above (does or does not) have a position where both ports are blocked. does not

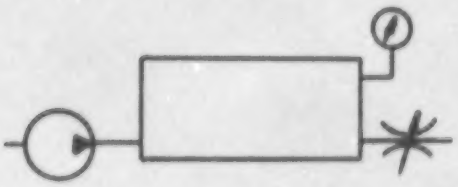
How many positions does a grease rack valve have? _____ three

Frame 20

Accumulators:

The output from a piston pump is an intermittent flow. During the filling stroke the outlet valve is closed, there is no flow in the outlet. Only during the pressure stroke is the outlet valve open; fluid is pressed out of the pump.

If it is desirable to have a constant flow of fluid, e.g. to an air pump in a gas station, a device is needed that will absorb the high flow during the pressure stroke and supply stored fluid during the filling stroke. Such a device is called an accumulator.



An accumulator can be a tank with an inlet and an outlet. The pressure in the tank varies according to the supply. It increases during the pressure stroke of the compressor and diminishes during the filling stroke. The output of the accumulator is a nearly constant flow.

The accumulator is also used to store fluid under pressure. The compressor works till a certain upper limit of air pressure in the accumulator is reached and is then shut off. If the amount of fluid needed by the circuit is only small, it can be supplied by the accumulator with little pressure drop. When the pressure finally reaches the lower limit,

Frame 20 (continuing)

the compressor is connected again and "reloads" the accumulator.

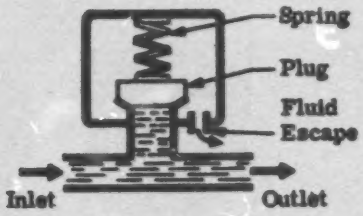
With this arrangement the compressor does not have to work continuously, thus saving energy and cost.

Frame 21

Pressure relief valves and pressure switches:

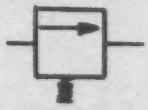
When the pressure in a fluid circuit rises above security limits the components are in danger.

The basic method of preventing further pressure rise is to permit fluid in the supply line to escape, thus relieving the pressure in the circuit.

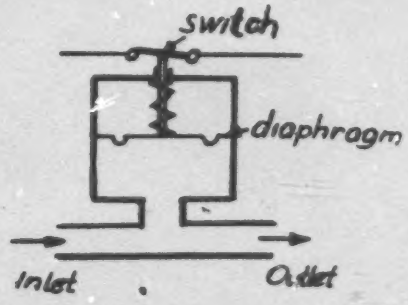


PRESSURE-RELIEF VALVE

The drawing shows a simple pressure relief valve. When the pressure in the line becomes larger than the pre-set spring pressure, the plug is pushed upward and fluid is allowed to escape through the opening. When the pressure has fallen to the desired level, the spring pressure counterbalances that of the fluid, the spring presses the plug down and the opening is closed. Symbol:



Pressure switches disconnect the compressor when the pressure in the circuit rises above the pre-set limit.



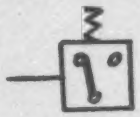
Like in the relief valve, when the pressure of the fluid becomes larger than the spring pressure, the diaphragm is bent up and the switch opens. Likewise, when the pressure of the fluid falls below the preset limit, the switch closes again and the compressor is restarted.

78

Frame 21 (continuing)

The pressure switch opens a contact when the fluid pressure becomes _____ than the preset limit. greater

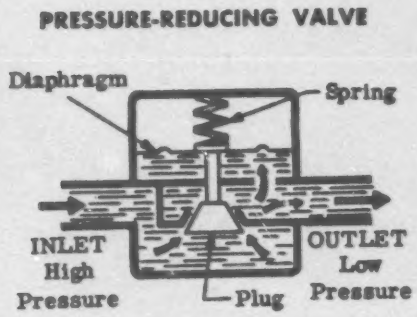
Symbol:



Frame 22

Pressure reducing valve:

Sometimes a continuous supply of fluid is needed at a pressure lower than that from the main supply line. This can be obtained by the use of a pressure reducing valve.



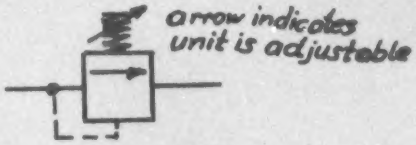
When the pressure in the outlet line is lower than that desired, the spring pressure pushes the plug down and the fluid passes through to the outlet line. As the pressure in the outlet line increases, due to the accumulation of fluid, pressure is transmitted to the diaphragm above the plug. Increases in pressure in this upper chamber force the plug up, and the opening between the supply and the outlet is gradually closed. When the pressure in the outlet line reaches the desired level, the plug completely closes the opening. Since fluid can no longer enter the outlet line, the pressure in that line can no longer increase. If the fluid in the outlet is consumed by the processing, the pressure decreases. This permits the spring to press the plug down and allow additional fluid into the outlet, until the desired outlet pressure is restored.

Frame 22 (continuing)

The plug closes the opening between inlet and outlet when the pressure in the outlet _____ the reaches preset limit.

The pressure reducing valve maintains the _____ outlet side of the valve at a constant pressure.

Symbol:



Frame 23

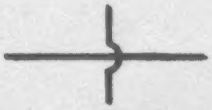
Symbols:

Some of the symbols have already been shown in the preceding frames. This frame gives a summary of the most important symbols used in schematic diagrams.

Working lines

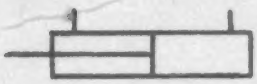
Exhaust lines

Working lines connected

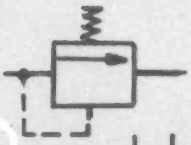


Working lines crossing, but not connected

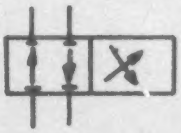
Compressors, pumps



Cylinders with two ports (double acting)



Pressure relief valve or pressure reducing valve

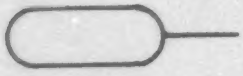


Two position 4 port valve

Check valve (one way valve)

Restriction valve

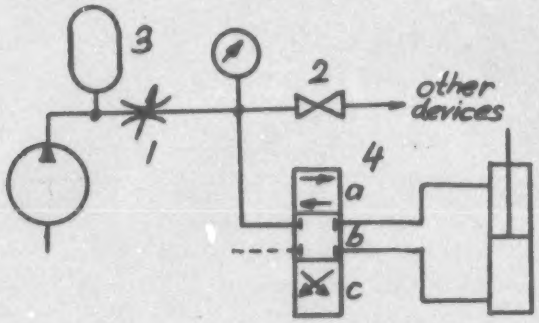
Shut-off valve



Accumulator

Frame 24

Now you have the fundamentals of fluid systems, let us look at some practical applications.



Can you identify the components? If not, recheck the symbols in frame 23.

Which device controls pressure and flow in the system? _____

restriction valve (1)

Does the circuit have protection against excessive pressure? _____

no

What type of cylinder is shown in the diagram? _____

double acting

With valve (4) in position a, where is the piston going? _____

downward

Trouble-shooting:

Knowing how the components of a fluid circuit work together, you should be able to localize malfunctioning elements of the circuit; a process called troubleshooting.

Suppose the cylinder does not move.

To localize the trouble causing component, you have to proceed with a logical step by step procedure.

Frame 24 (continuing)

The first logical step is to read the pressure gage. If the gage indicates a pressure above the lower limit of the working pressure of the cylinder, the circuit from the compressor to the gage is probably okay.

Assume that the gage indicates the correct pressure. The next step is to check the outlet of the valve. This can be done by connecting a pressure gage to the outlet of the valve.

If the gage indicates normal pressure, the fault must be located behind this point, i.e. either in the line to the cylinder or in the cylinder itself.

Actually, the process of trouble-shooting is relatively simple once the function of the interacting components is fully understood.

What would be the next step if the pressure gage (step 1) indicates insufficient pressure?

Shut shut-off valve (2). If the pressure rises, the circuit behind shut-off valve (2) is draining the main circuit, or the compressor cannot keep up with the demand (too small, belt slipping, coupling, etc.)

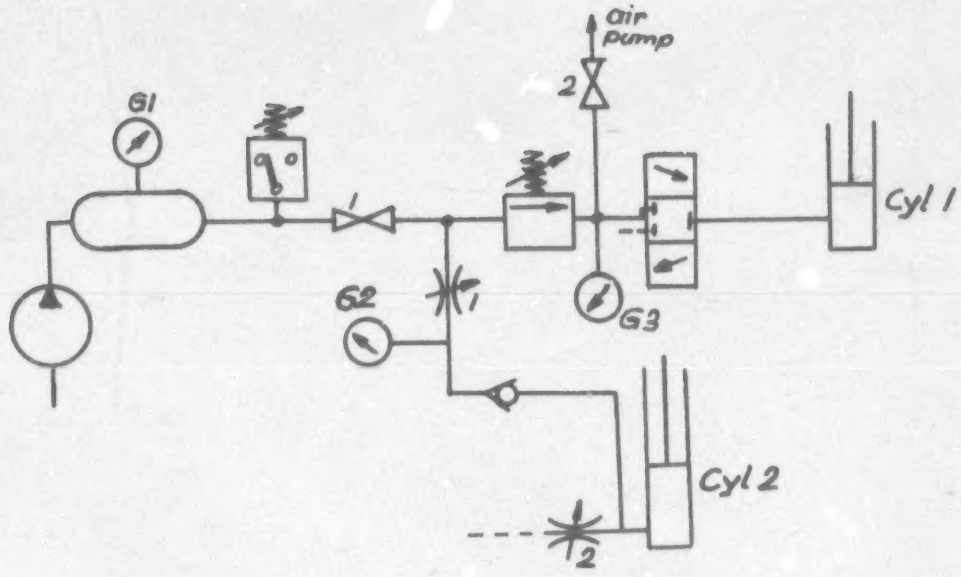
Frame 25

What we actually did was to follow the flow of the fluid through the circuit and check for interruptions.

And that is what trouble-shooting is all about. From our example we can derive the following general procedures:

1) Identify the components of the system, machine or apparatus you are working with.
2) Determine the relationship between the elements (e.g. which element supplies fluid to which valve or cylinder)
3) Sketch a schematic diagram of the device or machine. (If you have a diagram supplied by the manufacturer you save yourself some trouble)
4) Locate checkpoints along the flow path.
5) Find an adequate instrument (gage) and carry out your checks.

Frame 26



The diagram shows an example of a pneumatic system that serves 2 cylinders and an air pump.

Cylinder 1 is controlled by a three position valve, while cylinder 2 is controlled by two restriction valves.

Establish the logical steps for trouble-shooting the circuit when the following malfunctions occur:

Case 1: Cylinder 1 does not work at all, while cylinder 2 works fine.

Case 2: Cylinder 2 rises slowly but does not stay up when the restriction valve (1) is closed.

Case 3: The compressor works without stopping, but neither cylinder is actually in use.

Write your answers on a piece of paper and compare with the suggested answers on the following page.

Frame 26 (continuing)

Your sequence of steps may not be exactly the same as suggested here and still be a workable solution.

Case 1:

Step 1: Check G3, if okay, fault is from there to cylinder 1, if too low,

Step 2: Close shut-off valve (2).

Step 3: Read G3, if okay, air pump circuit drains the system. Check for leakage.

If G3 reads still low,

Step 4: Close restriction valve (1). Read G3. If okay, circuit of cylinder 2 drains the system. Check for leakage.

If G3 is still low,

Step 5: Check the components between the "T" and cylinder 1. If all the components are okay, there must be either leakage or a restriction in the lines.

Case 2:

Step 1: Check closure of restriction valve (2)

Step 2: Check for leakage in lines and cylinder.

Frame 26 (continuing)

Case 3:

Step 1: Read G1, if below the max. pressure set on the pressure switch, close shut-off valve (1).

If G1 reading increases and compressor stops after a while, system is okay up to shut-off valve (1).

Step 2: Reopen shut-off valve (1) and close:

a) Restriction valve (1), read G2, if G2 maintains the same value as G1, the circuit of cylinder 2 is okay.

b) Close shut-off valve (2), read G1, if the pressure begins to increase, failure is likely to be in the circuit of the air pump.

If G1 reading does not change,

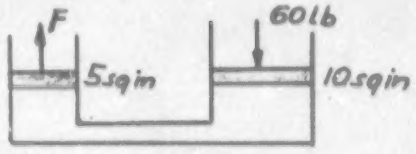
Step 3: Check lines and components of the straight line shut-off valve (1) to cylinder 1 for leakage.

Post-test

1) The most common unit of pressure measurement is:

a) foot per pounds
b) pounds per foot
c) pounds per inch
d) pounds per square inch

2) The force F is:



a) 30 lb
b) 60 lb
c) 90 lb
d) 120 lb

3) The pressure in the circuit shown in the drawing is:

a) 3 psi
b) 6 psi
c) 9 psi
d) 12 psi

4) The output speed of a hydraulic circuit (speed of a piston) depends on:

a) the pressure
b) the weight (or force) on the piston
c) the flow rate
d) the stroke of the cylinder

5) The power of a fluid circuit depends on:

a) the pressure and the speed of the piston
b) the pressure and the flow rate
c) the pressure and the area of the piston
d) the flow rate and the force of the piston

6) In a piston pump during the pressure stroke _____

a) the inlet valve is open and the outlet valve is closed
b) the inlet valve is open and the outlet valve is open
c) the inlet valve is closed and the outlet valve is open
d) the inlet valve is closed and the outlet valve is closed

7) A pressure relief valve _____

a) maintains a constant pressure in a circuit
b) controls flow to a cylinder
c) protects the circuit against excessive pressure
d) is sometimes used as a main valve

8) The symbol shows a

a) shut-off valve
b) three-way valve
c) selector valve
d) restriction valve

9) A pneumatic piston has a bore of 6 inches and a stroke of 10 inches. The flow rate of the air supply is 5 cubic feet/min., at a pressure of 50 psi.

Calculate: the horsepower of the air supply and the time the piston needs to travel its full stroke (use the formulas in frame 17)

10) Using the diagram in frame 26 indicate the steps you would take for trouble-shooting when the piston in cylinder 1 moves too slowly.

Answer Sheet

1) a b c d

2) a b c d

3) a b c d

4) a b c d

5) a b c d

6) a b c d

7) a b c d

8) a b c d

9) Horsepower =

Speed =

Time =

10) Step1 _____

Step2 _____

Step3 _____

Step4 _____

Step5 _____

APPENDIX B

Self Instructional Module

Introduction to Mechanization

INTRODUCTION TO MECHANIZATION

General Goals:

To introduce the trainee to the principles of the function of simple production machines.

To develop a basic understanding of the interaction between the different parts a machine is made of.

To indicate procedures used for localizing malfunctions within the system.

Performance Objectives:

After receiving this instruction the student should be able to:

1) Identify the basic components of a simple machine.
2) Identify at least three energy converters.
3) Identify the three forms of power and indicate ways of conversion.
4) Show capacity to interpret simple schematic diagrams.
5) Describe a systematic step by step procedure for trouble-shooting in a simple machine or system.

The content of this instruction is arranged in form of a self instructional module (SIM). Information is presented to you in small units. At the end of each frame or during the text you will be asked questions about material previously presented. You will find the correct answers on the side of the page.

Example:	
Bowling Green State University is located in _____.	Ohio
The Technology Building is located in the _ (northern or southern) _____ part of the campus.	northern

It is recommended to conceal the answers while you are working with the material. After you put down your own answer, you can check its correctness by comparing it with the given answer.

Sometimes you will use words in your response that are different from the ones given as the correct response. As long as the meaning is the same, your answer can be considered correct. If you cannot answer a question correctly, go back and reread the information leading to the question. If after careful rereading of the information you still have problems understanding the information ask the instructor for help.

Even relatively simple machines look often very confusing to a non-expert.

Sometimes, this first impression changes when a closer look is taken. Generally speaking, we can divide the parts a machine is made of into four types of elements.

These elements:

a) convert energy;

b) convert power;

c) transmit power; or

d) control the flow of power.

The interaction of a series of these blocks makes a machine function.

On the following pages we will analyze each of the four blocks separately and then study their interaction.

Frame 1

Energy is needed to do work. To have a hamburger at McDonald's several energy sources are used. First, you have to move yourself to McDonald's. There the waitress has to invest energy when taking your order. Heat energy is needed to prepare your hamburger and finally you have to deposit it in your stomach, which also requires energy. It is therefore correct to say:

Work can only be done when _____ is available. | energy

A machine needs energy to do its job. This energy must be easy to transform (e.g. from electrical to mechanical), and easy to transport (from a source to a consumer). If a form of energy satisfies these criteria, it is called power.

Power is therefore a type of energy that is easy to _____ and to _____. | transport; convert, transform

Frame 2

The forms of energy dealt with in this SIM are:

Thermal energy (heat); and

Photo energy (light).

The forms of power are:

Mechanical power;

Fluid power; and

Electrical power.

Mechanical power is, for example, contained in a spinning shaft, a moving car and a thrust forward projectile. When a piece of solid material (shaft, car, projectile) is moving, it bears mechanical power.

Fluid power is present in: a) liquids and gases under pressure; and b) liquids and gases in motion. For example, the wind (air masses in motion), a hydraulic jack (oil under pressure), or a steam engine (steam under pressure).

Electrical power is not as visible as the two other forms of power. We cannot see electricity, we can only see its effects. For example, in electric motors, electric heaters, electric lights.

The flowing water of a river bears _____ power. | fluid

The crank shaft in a car transmits _____ power from the engine to the rear axel. | mechanical

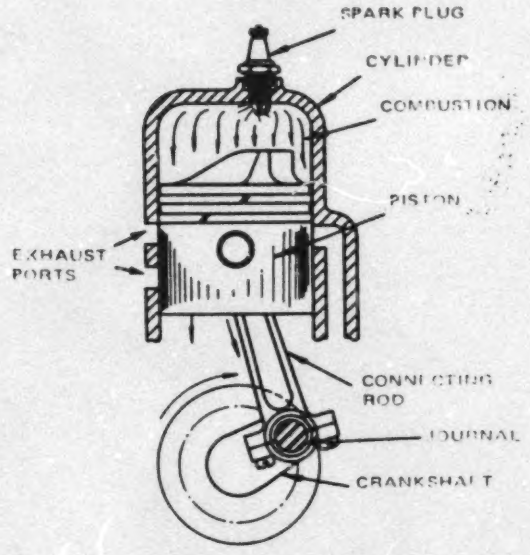
An electric oven converts _____ power into _____ energy. | electrical thermal

Frame 3

Thermal energy to fluid power converters:

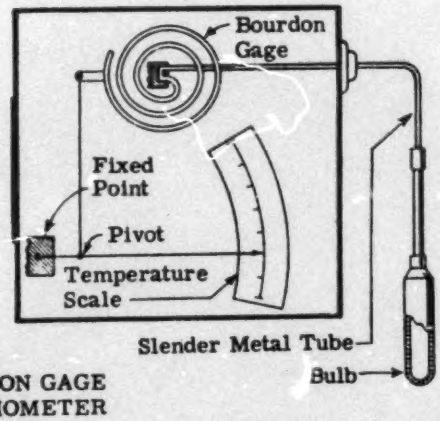
There are two types of thermal to fluid converters

a) Conversion by combustion



For example, in a car engine a gasoline air mixture is ignited and burns generating gases under pressure (fluid power). The piston is pushed downward by the expanding gases, thus converting fluid power to _____ mechanical power.

b) Direct converters



BOURDON GAGE THFRMOMETER

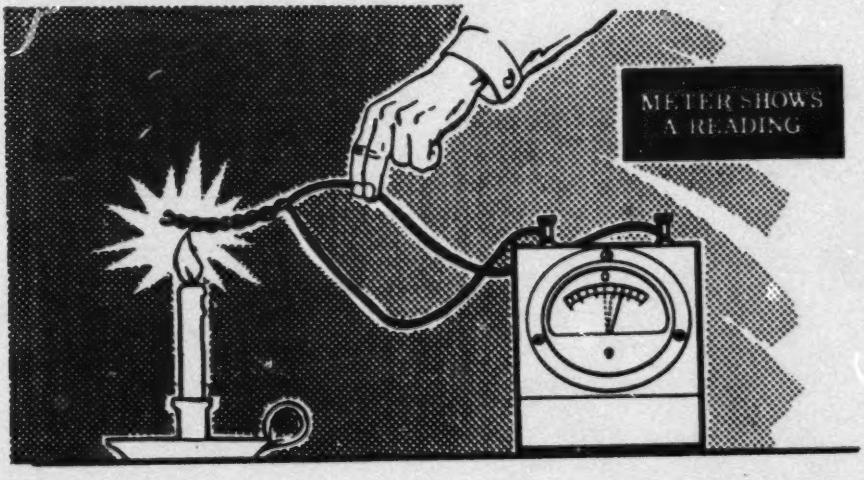
Direct converters are often used for measuring temperature. A gasbulb is located where the temperature is to be measured. Increasing heat produces increasing gas pressure in the bulb, which can be measured by a pressure (Bourdon) gage.

The fluid power (gas pressure) generated in the bulb is proportional to the _____ energy supplied to the bulb. heat

Frame 4

Thermal energy to electrical power converters:
Several devices are used to convert thermal energy to electrical power. These converters are often used for measurement purposes (e.g. thermocouples), or for portable sources of electrical power (e.g. fuel cells).

A thermocouple consists of two dissimilar materials, e.g. an iron and a copper wire, that are joined together. When the junction is supplied with heat energy, the device produces electrical power. This power is proportional to the temperature in the junction. This device can work as a perfect thermometer.

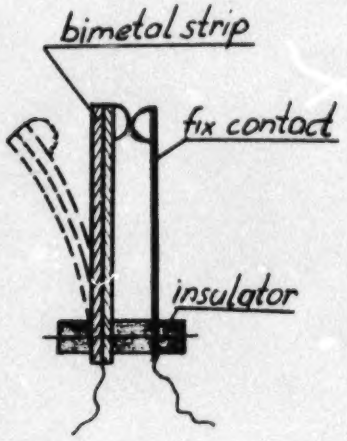


A thermocouple can be used, e.g. for measuring the _____ temperature in a furnace.

Frame 5

Thermal to mechanical converters:

These converters are only practical for use in control devices. For example, a bimetal switch can be used to control the temperature in an electric oven.



Two strips of different metals are fastened together. As the temperature increases, the two metals expand at different rates. Since they are impeded to slide one alongside the other, the strip bends. One end of the bimetal strip is anchored. The other end is fitted with an electric contact. When the oven is cold, the bimetal strip is in its vertical position, and the contacts are closed. When the temperature rises above the desired limit, the strip bends and the contacts open, interrupting the flow of power to the oven.

Bimetal devices work because different metals expand at (same or different) rates when the temperature rises. different

One end of the bimetal strip is firmly anchored and the other end is allowed to _____ when the temperature increases. move

Frame 6

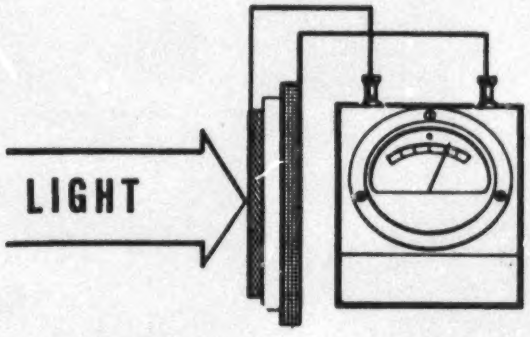
Photo energy to electrical power converters:

Photo -- electrical converters are used as

solar cells, and

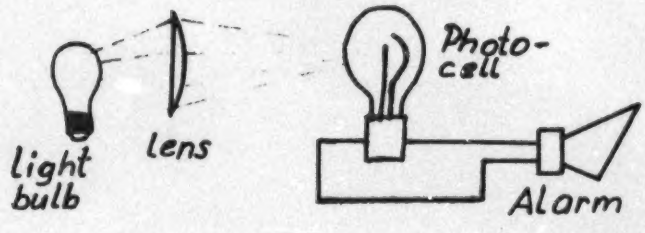
photo cells.

Solar cells are used, e.g. as energy sources for space crafts. They transform the energy of the sun directly into electrical energy. Photo cells are only used for control purposes. Applications: Light meter in photography, alarm systems, control relay for street lights.



In a light meter, the electrical power produced by the photocell is proportional to the intensity of the light. More light produces more

_____ _____. electrical power



When the light beam is interrupted, the electrical power produced by the photocell (decreases or increases). This change in power output can be used to trigger an alarm, close a relay, etc. decreases

Frame 7

Power converters are devices that transform power from the form it is available to the form it is needed for a specific application.

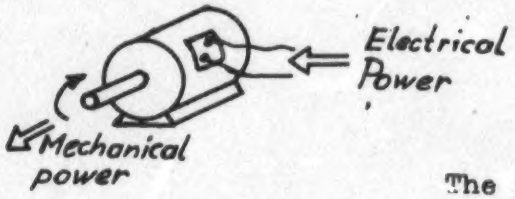
Motors, pumps, turbines, pistons are examples of _____ _____. power converters

In the following frames some of the most common power converters will be discussed.

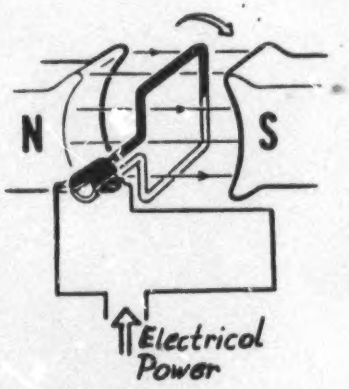
Frame 8

Electric Motors:

Electric motors receive electrical power through wires and transform it into mechanical power in the form of a spinning shaft.



Symbol for electric motor:



The principle of an electric motor is the law of Lenz. A conductor located within a magnetic field will move when a current flows through the conductor. With the right arrangement of conductors and magnetic fields a circular movement can be produced.

Some motors can be used as generators. In this case the power flow is inverted. Mechanical power is supplied through the shaft and electrical power is produced in the wires.

If an electric motor does not work properly, the first check would be to see if it receives electrical power in the right form and amount.

An electric motor takes _____ power and converts it into _____ power. — electrical, mechanical

In order to work properly, a motor must receive the right form and amount of _____ _____. — electrical power

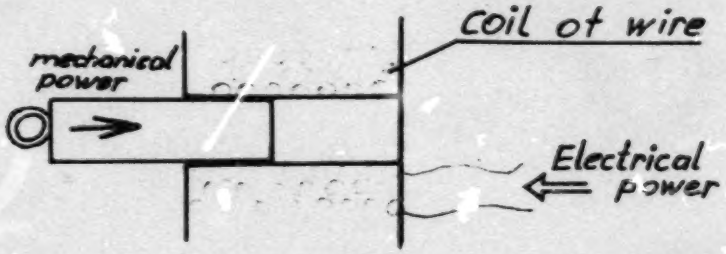
Frame 9

Solenoides:

Solenoides convert electrical power into mechanical power in the form of a linear movement of the plunger.

When a coil of wire is connected to a source of electrical power, a magnetic field is created by the coil.

This magnetic field attracts the iron plunger with a force proportional to the input of electrical power.



Solenoides are often used to control valves, switches, clutches, etc.

When a solenoid receives electrical power, a magnetic field is created. This magnetic field can _____ an iron plunger, thus converting electrical power into _____ power.

attract

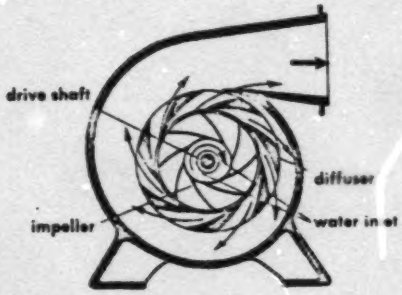
mechanical

Frame 10

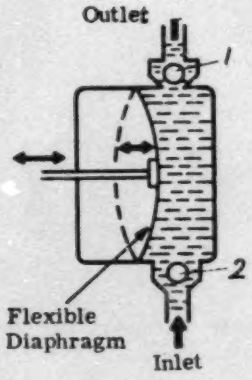
Pumps, turbines and fluid motors:

Fluid power is carried by liquids in motion (e.g. a river) and gases under pressure (e.g. a tire pump).

There are many types of pumps in use. One example is the centrifugal pump.



The fluid enters the pump axially and is accelerated by the impeller. Centrifugal forces press the fluid out through the diffusers to the outlet.



DIAPHRAGM PUMP

Another interesting type of pump is the diaphragm pump. When the diaphragm is pulled back, the volume of the pump chamber increases and liquid is drawn in from the inlet. Valve 1 (outlet) is drawn shut; valve 2 (inlet) pushed open. When the diaphragm is pushed foreward again, valve 2 is pushed shut and the liquid is pushed out through the outlet valve.

Pumps convert mechanical power into _____ power. fluid

In the centrifugal pump, the liquid is _____ by the impeller. accelersted

In the diaphragm pump, the inlet valve is _____ when the diaphragm is pushed forward. shut

Frame 11

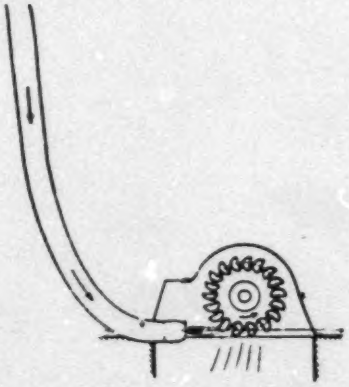
Pumps, turbines and fluid motors (continued)

Some pumps can be used as fluid motors (e.g. the centrifugal pump described in frame 10 could be used as a motor). Fluid under pressure enters the inlet and pushes against the impellers, thus creating a circular movement.

Could a diaphragm pump be used as a fluid motor? _____ no

(Basically the same arrangement as used in the diaphragm pump can be used as a fluid motor, but the valves would have to be changed.)

Another type of fluid power to mechanical power converter is the turbine.



The drawing shows a Pelton wheel, which is a type of turbine used in some hydraulic power plants. The stream of water is directed against the vanes of the turbine, producing a rotary motion.

When trouble arises with a fluid converter, check the continuity of the circuit and the power input for appropriate magnitude.

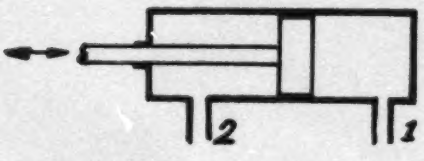
For example, if the outlet of a centrifugal pump is blocked, the pump (can or cannot) work. cannot

Valves are also a common source of trouble. A leaking valve in a diaphragm pump means that the pumping action of the diaphragm is _____. ineffective

Frame 12

Cylinders:

Cylinders are devices that are extensively used to convert fluid power into mechanical power (linear movement). Their advantage is their ability to effectively produce large forces and their ease of maintenance.



When a pressurized fluid enters inlet 1, the piston rod is pushed out. For this arrangement, inlet 2 must be _____, in order to allow the piston to move to the left. open

When pressurized fluid enters inlet 2, the piston is pushed back. The force of the push is proportional to the pressure of the fluid and the area of the piston. A small piston (will or will not) produce as great a force as a large piston, provided the pressure is equal in both. will not

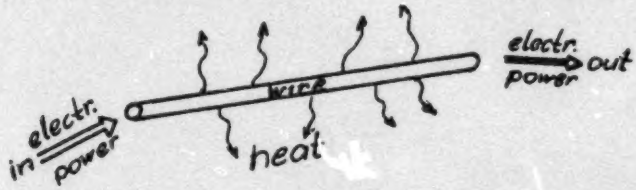
Frame 13

Converters of electrical power to heat and light energy: When electrical power passes through a wire, it has to overcome a certain opposition (resistance). The power employed to overcome this opposition is converted into heat energy.

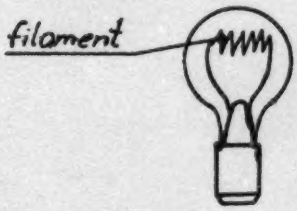
Toasters, heat lamps, electric ovens and light bulbs work on this principle. They transform electrical energy into _____ energy.

heat

The amount of heat produced depends on the amount of electrical power passing through the device and on the resistance of the wire.



The electrical power entering the wire is equal to the electrical power exiting plus the heat produced.



A light bulb works on the same principle. The temperature in the filament is so high that it becomes incandescent, i.e. light emitting.

The heat or light energy produced by this type of converter is proportional to the _____ power supplied.

electrical

Frame 14

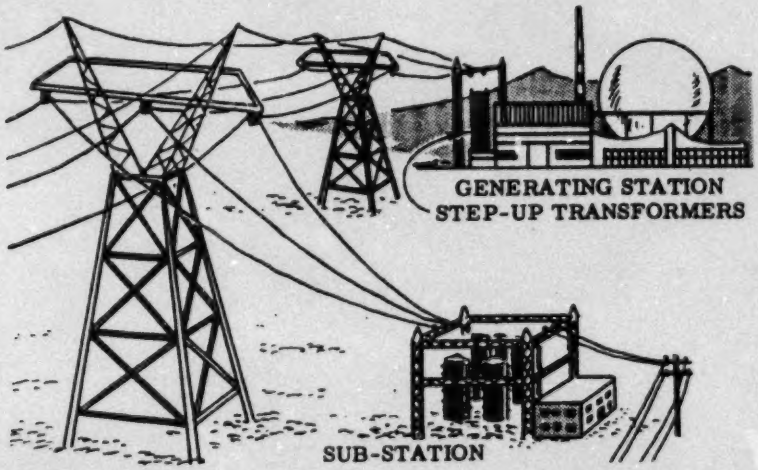
Power transmission devices:

Power is usually not produced where it is needed.

In a car, mechanical power is produced in the engine in the front part of the car. From there it is transmitted by gears, the clutch and the drive shaft to the wheels.

It is the job of the power transmission devices to transport power, change its parameters and control its flow.

Electrical power produced in huge power plants must be transmitted via power lines and transformers to the consumer.



And finally, fluid power is conducted by hoses, pipes and tubes to where it is needed.

Frame 15

Power transmission devices (continuing)

Power transmission devices are potential trouble areas. When a device does not work properly, check the power input first. Make sure the device receives the right amount of power.

Power transmission devices not only include conducters (wires, hoses, etc.) but also control elements, such as switches, fuses and valves.

Switches, valves, fuses and clutches are parts of _____ _____ systems.

power transmission

Devices that change the parameters of power are also part of the power transmission systems.

Gears change the relationship of speed to force in mechanical power.

Transformers change the relationship of voltage and current flow in electrical power.

Gears or transformers are used when the relationship of the parameters of the _____ involved must be changed.

power

Frame 16

Power storage devices:

Power storage devices are used:

a) to supply power to nonstationary machines (e.g. car batteries, space crafts, flash lights); and

b) when a large amount of power is needed during a short time period. A relatively small power source is continuously charging a storage device. When the consumer needs a large "power push", it is drawn from the storage device.

Flywheels and springs are examples of _____ power storage devices.

mechanical

A water tower is a fluid power _____ _____.

storage device

A battery is an example of an _____ _____ storage device.

electrical power

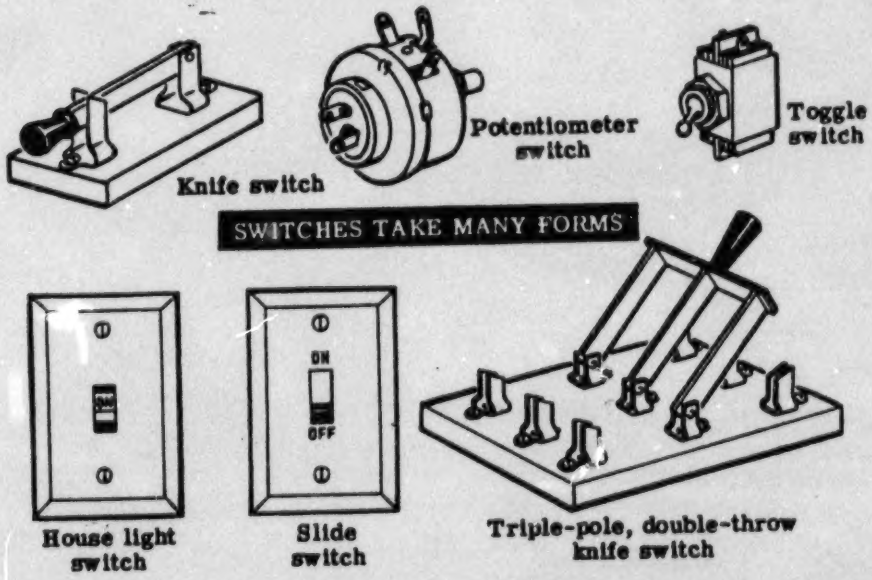
Frame 17

Electrical power control elements:

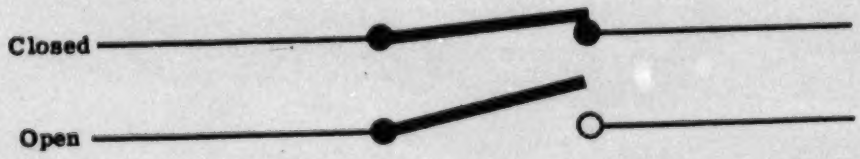
Devices for the control of electrical power will now be discussed.

There exists a large variety of control elements, from simple manual switches to automatic process controllers. In the context of this SIM, only simple manual control and protection devices will be considered.

Switches are the most important control devices for electrical power. They connect or interrupt the power supply to a machine.



The symbols used in schematic diagrams are:



Switches are devices that control the flow of _____ electrical power.

Frame 18

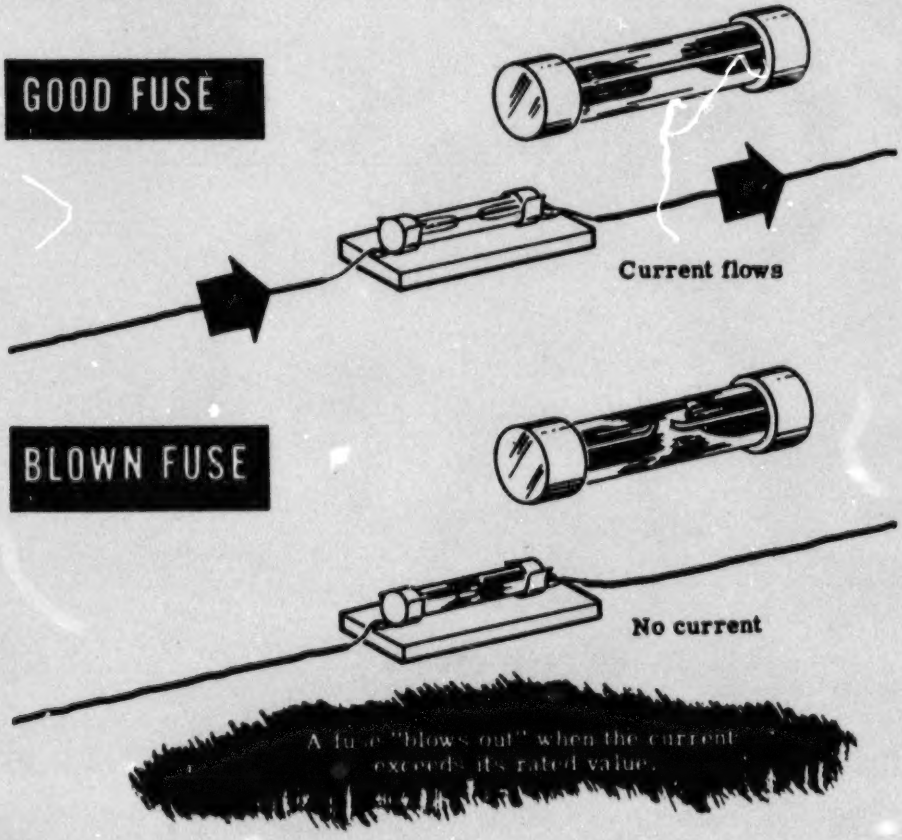
Electrical power control elements (continuing)

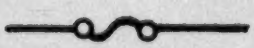
Fuses and breakers:

Electrical devices are designed to accomodate a certain amount of power. If too much power is supplied, the circuit has to be interrupted to avoid damage.

This job is done by fuses and breakers; they protect the circuits behind them.

Fuses are weak points (thin wires) placed within the transmission system. They are put in accessible locations, so they can easily be checked and replaced.



The schematic symbol for fuses is: 

Frame 19

Electrical power control elements (continuing)

Breakers have the same function as fuses, namely to _____ machines, circuits and devices.

protect

The difference is simply that breakers can be reset when they "blow", while fuses have to be replaced.

When a fuse or a breaker is selected for a particular circuit, it must be of the right size. Protection devices with too low a capacity will blow when everything is still okay.

Conversely, protection devices with too large a capacity do not offer adequate protection.

Care has to be taken when selecting a protection device, so it is of the _____ size and type.

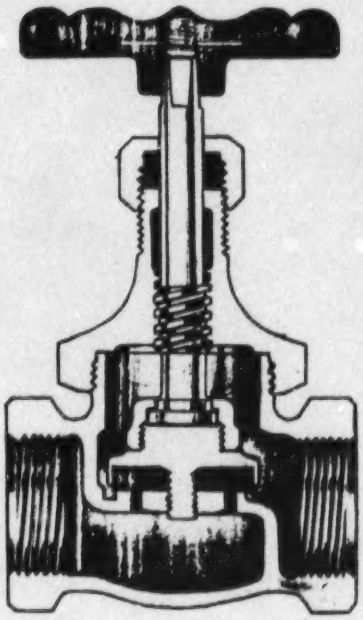
right, correct

Frame 20

Valves:

Valves control the flow of fluid power.

Many different types of valves are used in fluid devices.

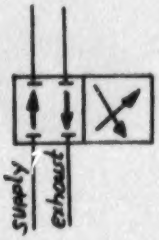


A simple, often used type of valve is the shut-off valve. The shut-off has only two positions. It is either open or shut. Its symbol is:

The restriction valve (shown in the drawing) regulates the flow of fluid. A popular example is the valve in a sink or bathtub. The symbol of the restriction valve is:

Other valves only permit the passage of fluid in one direction. These valves are called one way or check valves.

Their symbol is:



This symbol represents a valve that has two outlets on each side. When the position of the valve is inverted, the in- and outlets are exchanged. This type of valve is often used for controlling cylinders.

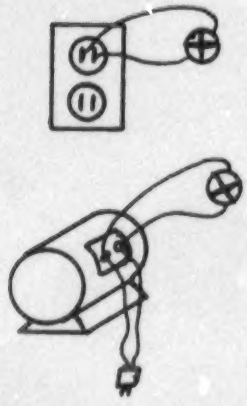
Frame 21

Measuring devices:

When observing mechanical power transmissions it can be determined by simple observation whether "something is happening" or not. If an axel is turning, it must be receiving mechanical power. In electrical or fluid systems it is often impossible to observe power flow without instruments.

Instruments to measure electrical power are:

Testlights



A testlight is a simple light bulb with two leads of wire. We use it to check for the existence of electrical power in an outlet, the connectors of a motor, a light socket, etc.

When the light goes on, electrical power (is or is not) available in the test point. | is

A spinning axel indicates the existence of _____ power. | mechanical

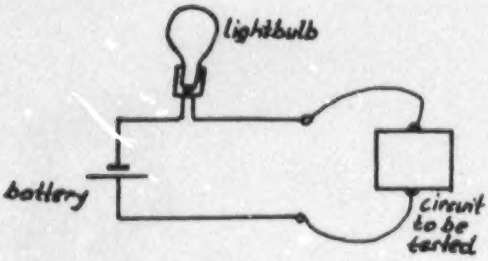
Continuity tester

An electrical device can only work when the supply line and the returnline from the power source to the device are not interrupted (open switch, blown fuse, bad contact, etc.).

A continuity tester is used to determine whether the lines are continuous or not.

Frame 22

Measuring devices (continuing)



A continuity tester consists simply of a light bulb, a battery and test leads. When the circuit to be tested is continuous, the light bulb goes on.

WHEN MAKING THIS TEST, BE SURE THE POWER SOURCE IS DISCONNECTED.

When checking for existence of electrical power a _____ is used. testlight

Checking circuits for interruptions is done with a _____ tester. continuity

When a continuity tester is used, the circuit or apparatus to be checked has to be _____ to/from its power source. disconnected

Frame 23

Measuring devices (continuing)

The parameters to look for in fluid systems are flow and pressure.

Flow can often be seen, e.g. through a transparent tube or hose. It can also be measured with a flowmeter.

In order to have flow in a system we need a circuit without interruptions and we need pressure.

Pressure is measured with a manometer or pressure gage.

When the pressure gage shows the correct pressure in the system and the apparatus does not work, check for restrictions in the conductors, a blocked valve or other causes that impede circulation.

A fluid system without pressure _(can or cannot)_ have flow. — cannot

Flow is controlled (limited) by valves and the devices (cylinders, turbines) activated by the fluid.

The instrument used for measuring pressure is a _____. — pressure gage

Frame 24

As long as everything works fine, everybody can be an operator or mechanic.

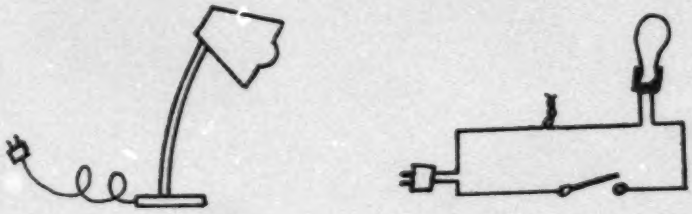
When a machine breaks down and you have to find out what is wrong, you have to know more than just how to press a button or open a valve.

But it usually looks more difficult that it really is.

When trouble-shooting, you have to be systematic; and that's the secret of the trade.

A few examples will show how to proceed.

Suppose your reading lamp does not work.



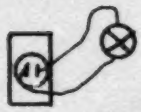
Probably your first reaction would be to replace the light bulb. You find a new bulb, put it in the socket--and nothing happens. Now it is serious, now you better find yourself some kind of measuring device, for example a testlight.

The first logical step is to see if the outlet is okay.

So you insert the test leads into the outlet.

The testlight lights up, the outlet is okay.

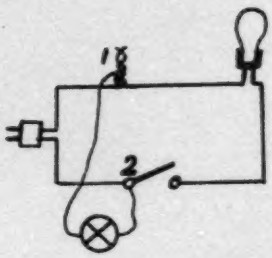
Frame 24 (continuing)



If the testlight does not light up, several things could have happened. For example, the testlight itself could be malfunctioning. Or the breaker could have opened.

For our example let's assume the outlet is okay.

The next step would be to check for the existence of electrical power in the interior of the lamp.



If the testlight lights up, the cord is okay, and the failure must be in the interior of the lamp.

What is the next step? (See if you can think about the next logical step).

Leave test lead 1 where it is and put lead 2 on the other side of the switch.

When opening and closing the switch, the light should go on and off.

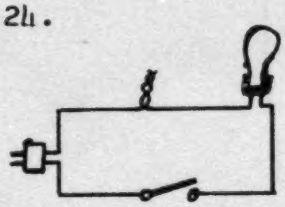
Okay, now you have probably grasped the idea.

During the whole procedure the plug was <u>(connected or disconnected)</u> to the outlet.

connected

Frame 25

Let's now analyze the system we were trouble-shooting in the example of frame 24.



The light bulb was our converter.

It converts _____ _____ into light energy. electrical power

The switch was the _____ element of the system. control

The wires and the plug were responsible for the transmission of the electrical power. They were our _____ power transmission.

What we actually did was to follow the flow of power and check for interruptions.

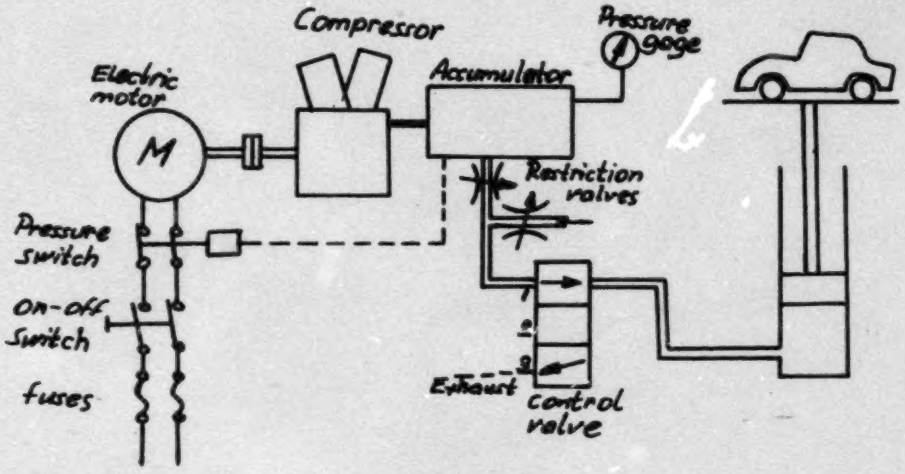
And that is what trouble-shooting is all about. From the example we can derive the following general procedure:

1) Identify the elements of the system, machine or apparatus you are working with.
2) Determine the relationship between the elements (e.g. what element carries power to which converter).
3) Sketch a schematic diagram of the device or machine with which you are working. (If you find a diagram supplied by the manufacturer you can save yourself some trouble.)
4) Locate checkpoints along the power flow.
5) Find an adequate instrument and carry out your checks.

Frame 26

You are now ready to apply the trouble-shooting procedure to a more sophisticated apparatus.

Our system is a hoist used to lift cars in a garage.



When the on-off switch is closed, the motor drives the compressor which sends air into the accumulator. When the pressure in the accumulator reaches a limit, the pressure switch interrupts the power flow to the motor and the motor stops until the pressure decreases below the limit set on the pressure switch.

The control valve has three positions. Pos. 1 -- air flows into the cylinder, the platform is lifted.

Pos. 2 -- the supply to the cylinder is blocked, the platform remains stationary. Pos. 3 -- the line to the cylinder is connected to the exhaust, the platform goes down.

Frame 26 (continuing)

The cylinder, the compressor, and the electric motor are _____ _____.

power converters

Mechanical power is transmitted between the _____ _____ and the _____.

electric motor compressor

The pressure switch, the on-off switch and the fuses control the flow of _____ _____ to the motor.

electrical power

Case 1:

The platform raises, but at a lower speed as usual.

Indicate the steps you will take to solve the problem.

(Answer on the next page)

Case 2:

The compressor does not work at all.

Case 3:

The platform can be raised but cannot be lowered.

Answers

Your answers might differ slightly from the procedure suggested here and still be correct.

Case 1:

1) Check pressure gage. If it shows the 150 psi, everything up to this point is okay.
2) Shut valve b and see if the platform raises at adequate speed. If so, there could be a leak in the air line to the filling station or in the filling station itself.
3) Check the air line from the accumulator to the control valve.
   (Valve must be open, look for leakage)
4) Check control valve and air line from valve to cylinder.

Case 2:

Check for the existence of electrical power (testlight)

1) after fuses
2) after on-off switch
3) after pressure switch
4) in connections of the motor

Case 3:

The problem can only be in the control valve or in the exhaust line (blocked).

Okay, that was it. Now we will see if you remember the highlights of the SIM.

Post-test

1) The three basic components machines are made of are _____

   a) power converters, connectors and switches
   b) cylinders, motors and power transmission lines
   c) energy converters, controllers and power transmissions
   d) power converters, energy converters and power transmissions

2) Switches, fuses, valves are parts of _____

   a) power transmissions
   b) energy converters
   c) power converters
   d) instruments

3) Fluid power can be converted to mechanical power by means of _____

   a) an electric motor
   b) a light bulb
   c) a solenoid
   d) a hydraulic motor or cylinder

4) A _____ is a device that converts electrical power into mechanical power.

   a) solenoid
   b) turbine
   c) hydraulic cylinder
   d) pressure switch

5) Fuses are used to _____

   a) connect and disconnect motors
   b) protect electrical devices
   c) control pressure
   d) check for electrical power

6) Electric motors receive electrical power and convert it into _____

   a) heat energy
   b) fluid power
   c) mechanical power
   d) photo energy

7) Fluid power is produced by _____

a) turbines
b) pumps
c) hydraulic jacks
d) solenoides

8) Gears, levers, shafts are means of _____

a) mechanical power conversion
b) controlling power
c) measuring the magnitudes of mechanical power
d) mechanical power transmission

9) When using a continuity tester you can check for _____

a) the right magnitude of electrical power in a check point
b) the continuity of the conversion process
c) the continuity of a transmission line
d) whether power is available or not in a checkpoint

10) If you want to check the pressure of a fluid you would use a _____

a) flow meter
b) a test lamp
c) a continuity tester
d) a manometer

11) Using the diagram of frame 26 indicate the steps to take when the platform raises too slowly and the pressure gage never reaches 150 psi.

Introduction to mechanization

Answer Sheet

1) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

2) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

3) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

4) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

5) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

6) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

7) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

8) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

9) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

10) $\frac{\_}{a}\ \frac{\_}{b}\ \frac{\_}{c}\ \frac{\_}{d}$

11) Step 1 _____

Step 2 _____

Step 3 _____

Step 4 _____

Step 5 _____

APPENDIX C

Decision Matrix for Choosing the Method of Instruction

Criterion

Training Methods	control of learning	educational impact	time needed for instruc	ease of production	ease of scheduling	summative score
Weightfactor	.1	.3	.1	.2	.3	
pure lecture	2 / .2	3 / .9	4 / .4	5 / 1.	0 / 0	2.5
lecture with audio vis. supp.	2 / .2	5 / 1.5	3 / .3	3 / .6	0 / 0	2.6
video tape	1 / .1	3 / .9	5 / .5	1 / .2	5 / 1.5	3.2
audio tape	1 / .1	0 / 0	4 / .4	3 / .6	5 / 1.5	2.6
SIM	4 / .4	3 / .9	3 / .3	4 / .8	5 / 1.5	3.9*
SIM and audio tape	4 / .4	4 / 1.2	3 / .3	2 / .4	5 / 1.5	3.8

* The best solution has the highest numerical value.

assigned score $\frac{2}{.2}$ score multiplied by weightfactor

APPENDIX D

Validation of the Instrument

Judge _____

SIM - Introduction to Mechanization	SIM - Introduction to Fluidics
How well does the content represent the conceptual approach to trouble-shooting training?	How well does the content represent the specific approach to trouble-shooting training?

(See definition of terms)

_____	_____	_____	_____	_____	_____
good	ok	poor	good	ok	poor

Difficulty of the material

1	2	3	4	5		1	2	3	4	5
easy				difficult		easy				difficult

Quality of style, form, drawings

1	2	3	4	5		1	2	3	4	5
good				poor		good				poor

Clarity of content, organization, pacing

1	2	3	4	5		1	2	3	4	5
good				poor		good				poor

Add other criteria:

Conclusion: Do you consider the instrument (the two SIMs and the performance test) as being valid for testing the hypotheses?

_____	_____
yes	no

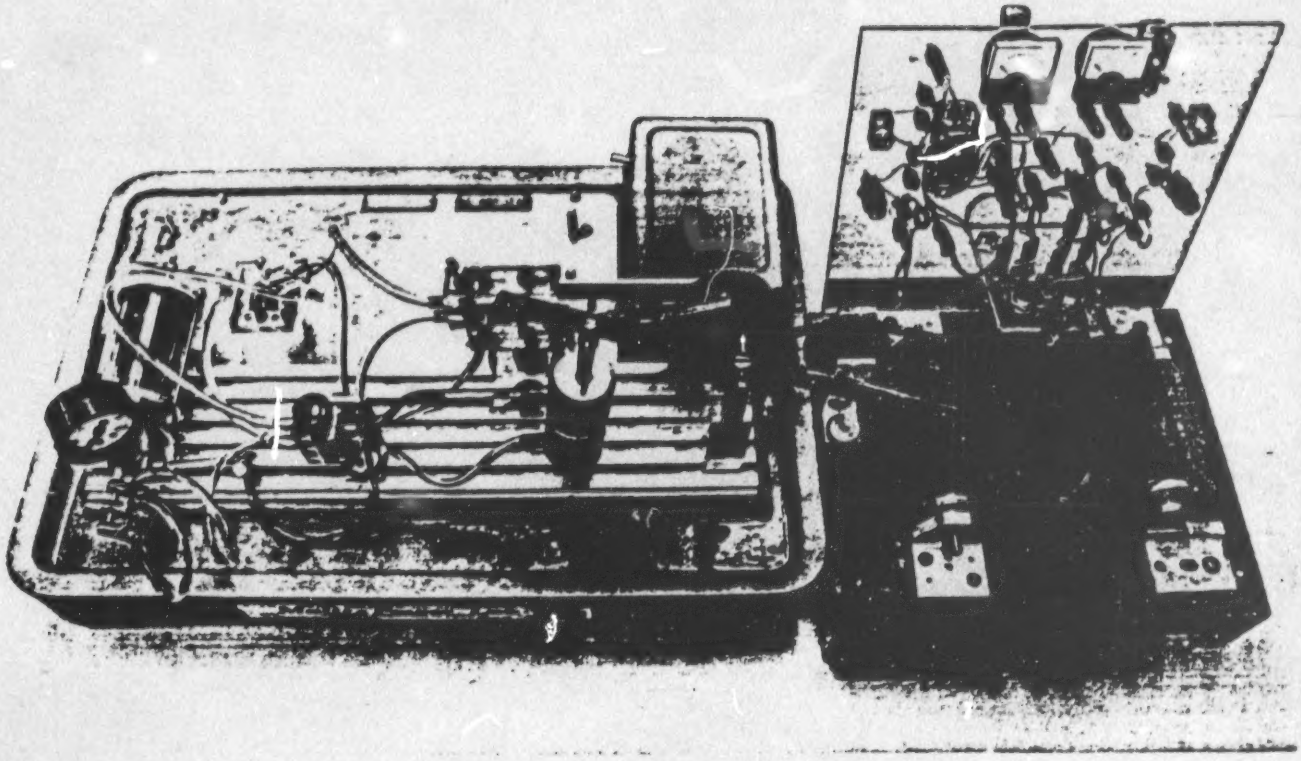
_____
Signature

APPENDIX E

PERFORMANCE TEST - SIMULATOR

THE SIMULATOR

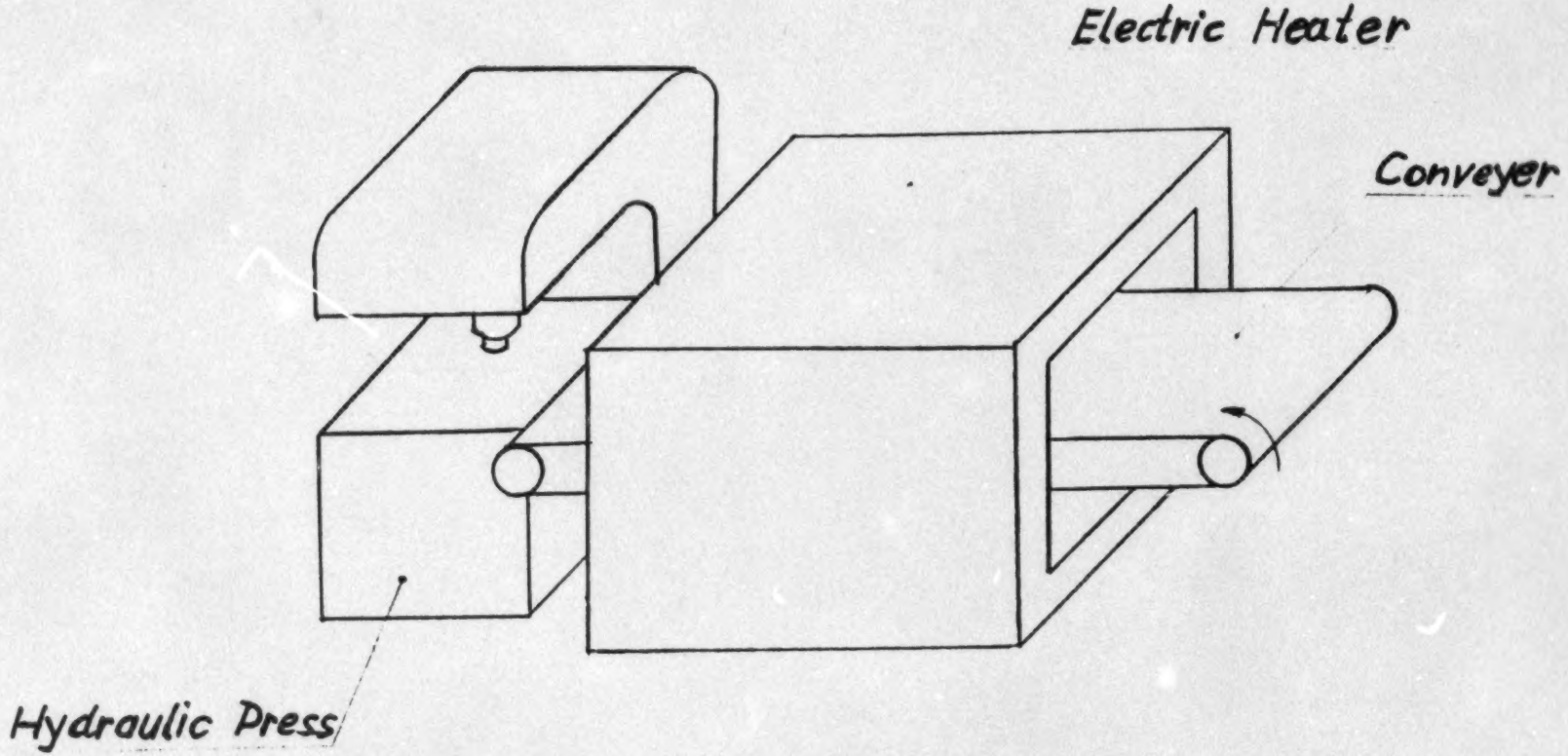
Electrical
Components

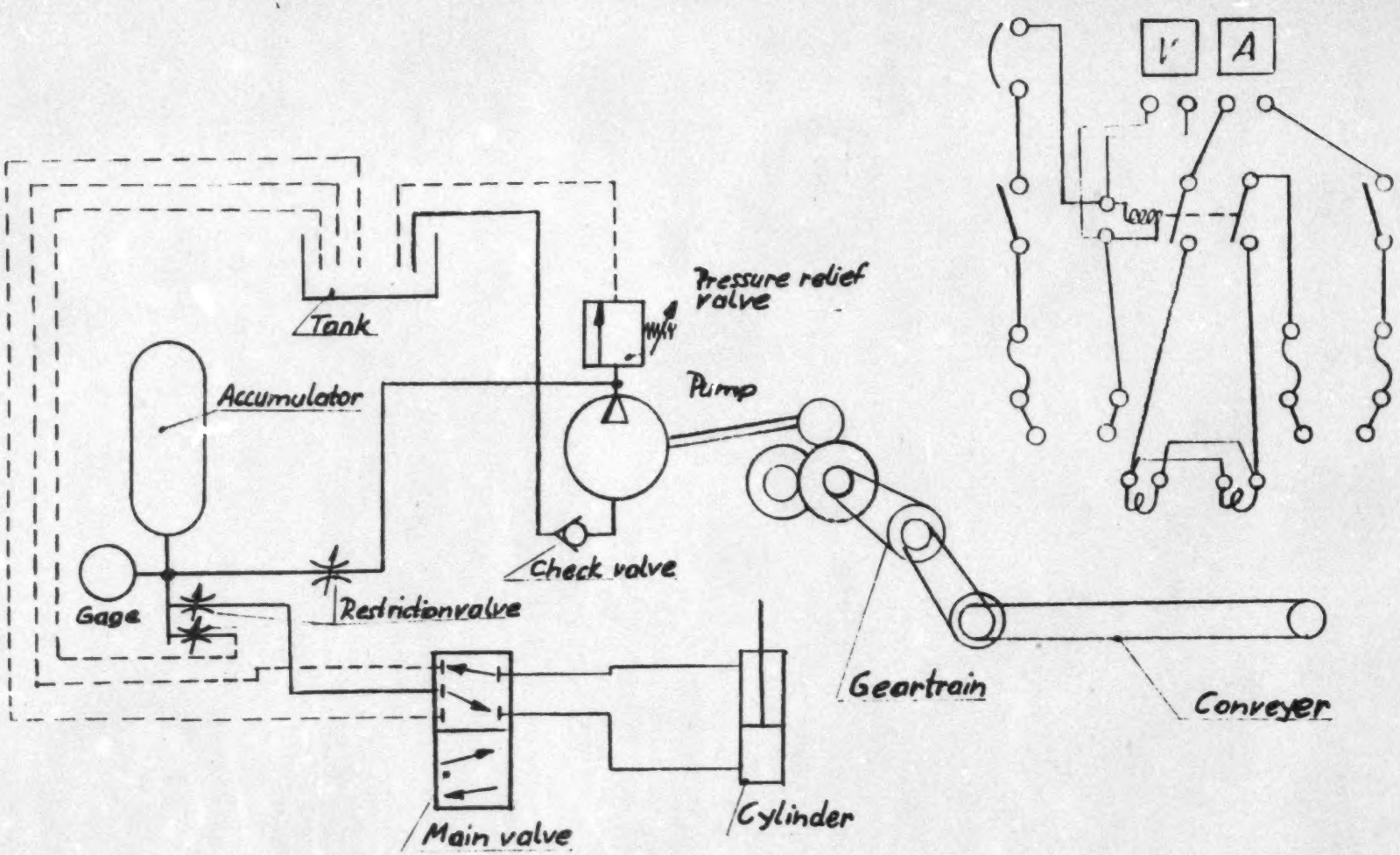


Fluid
Components

Mechanical
Components

Machine for pressfitting Bearings





Schematic Diagram

	Heatlamp		Temp. Control
	Fuse	V	Voltmeter
	Switch	A	Ammeter
	Relay		

A
V
Power
Control

List of the Malfunctions

Injected for the Performance Test

In the fluid components:

1) Check valve inverted.
2) Inlet of the cylinder obstructed.
3) Outlet of the cylinder obstructed.
4) Inlet of the main valve obstructed.
5) Restriction valve 2 closed.
6) Restriction valve 1 closed.
7) Restriction valve 3 open.
8) Inlet of the accumulator obstructed.
9) Relief valve set too low.
10) Exhaust main valve obstructed.

In the electrical components:

1) Interruption between bimetal switch and relays.
2) Fuse of the control circuit blown.
3) Fuse of the main circuit blown.
4) Both light bulbs burned out.
5) Interruption between lamp and relay.
6) Interruption between lamp 1 and lamp 2.
7) Contacts of the bimetal switch open.
8) Interruption between ammeter and switch.
9) Interruption between ammeter and relay.
10) Interruption between relay coil and power supply.

APPENDIX F

Oral Introduction to the Simulator

Show trainee the pictorial drawing of the machine for pressfitting bearings.

Describe: press, electric heater, conveyer

The part into which the bearing is to be fitted is placed on the conveyer and enters the heater. There it is heated, causing the metal to expand. The bearing is placed on the heated part at the opposite end of the conveyer and pushed into place by the press.

Explain simulator: (turn power on)

This simulator is a simplified representation of the machine just described. Here is the conveyer (show), driven by the same motor (show) as the hydraulic pump (show).

The electric heater is represented by these two heat lamps (show). The circuit of the heat lamps is mounted on this panel (show). It is divided into a control circuit and a power circuit (show on the schematic diagram and on the panel).

When the control circuit is closed, the coil of the relay is energized and the contacts are closed (show on diagram and on panel). The electrical power can then flow from the inlet (show) to the heat lamps. Each circuit is controlled by a switch and by fuses (show on diagram and on panel).

The control circuit has a temperature switch (show on the diagram and on the panel). This switch can be set to a specific temperature. When the heater reaches this set temperature, the contacts open (show), the current to the relay coil is interrupted, the relay contacts open and the heat lamps are turned off.

The hydraulic part of the simulator consists of: the pump, the pressure relief valve, the accumulator, the three restriction valves, the main valve, and the cylinder (show).

The pump pulls water from the reservoir through the one way valve (show) and pushes it into the accumulator (follow the flow line). The pressure gage (show) indicates the pressure of the system. It should be within these two marks (show).

One line goes from the accumulator to the main valve, and another line goes back to the reservoir. Both lines are controlled by restriction valves (show). The main valve sends the fluid either to the upper, or to the lower side of the cylinder, causing the piston to move (show).

Explain procedure:

Now you have seen how the system works. Do you have any questions?

Let us now test how well the instruction prepared you for trouble-shooting. Remember, this is not meant to test you as a person, but to test the effectiveness of the instruction you received. So you do not have to feel frustrated when you cannot resolve a problem.

Because you cannot see the flow of electricity by simply looking at the wires, we are providing you with a test light and a continuity tester (show). The test light is held between the plus and the minus contacts (show) and the light goes on when power is there.

The continuity tester helps you to check continuity of the circuit (show). When you use it, the power has to be turned off.

The voltage of the power supply is only 15 volts; you do not have to be afraid of receiving an electric shock.

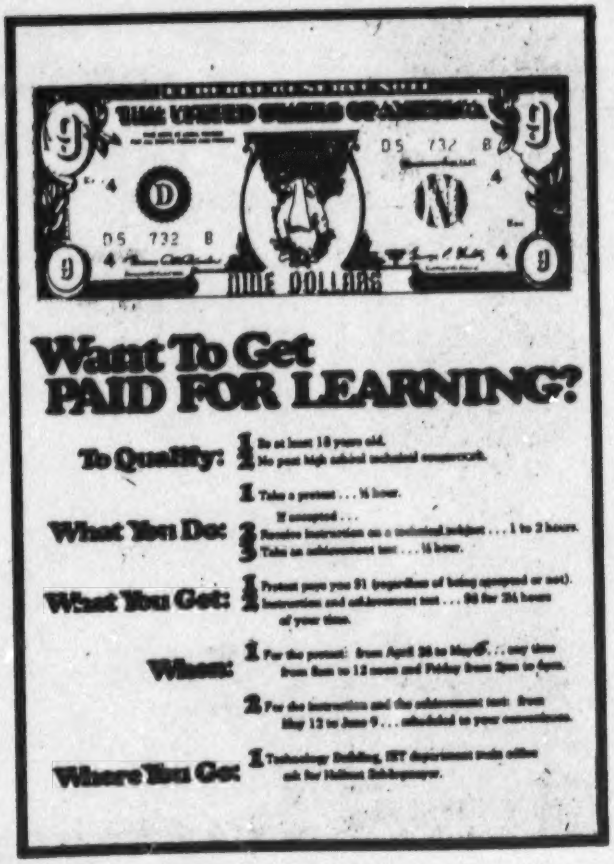
Would you now leave the room. After I bug the system you can begin your trouble-shooting.

APPENDIX G

Recruitment Tools

WANT TO GET PAID FOR LEARNING? To Qualify: Be at least 18 yrs. old. No post high school technical course-work. WHAT YOU DO: Take a pretest—½ hour. If accepted receive instruction on a technical subject — 1 to 2 hours. Take an achievement test — ½ hour. WHAT YOU GET: Pretest pays you $1 (regardless of being accepted or not). Instruction and achievement test, $8 for 2½ hours of your time. WHEN: for the pretest: from April 28 to May 3, any time from 8 a.m. to 12 noon and Friday from 2 p.m. to 6 p.m. For the instruction and the achievement test: from May 12 to June 9, scheduled to your convenience. WHERE YOU GO: Technology Building, IET department main office, ask for Helmut Schorgmayer.

Ad placed in
Bowling Green
Sentinel-Tribune
May 2, 1975



Ad placed in
Bowling Green
BG News
May 8 and 9, 1975

FLIER

FEDERAL RESERVE NOTE
THE UNITED STATES OF AMERICA
THIS NOTE IS LEGAL TENDER FOR ALL DEBTS, PUBLIC AND PRIVATE
D5 732 B
WASHINGTON, D.C.
D5 732 B
NINE DOLLARS

Want To Get PAID FOR LEARNING?

To Qualify:

1. Be at least 18 years old.
2. No post high school technical coursework.

What You Do:

1. Take a pretest . . . ½ hour.

If accepted . . .

2. Receive instruction on a technical subject . . . 1 to 2 hours.
3. Take an achievement test . . . ½ hour.

What You Get:

1. Pretest pays you $1 (regardless of being accepted or not).
2. Instruction and achievement test . . . $8 for 2½ hours of your time.

When:

1. For the pretest: from April 28 to May 3 . . . any time from 8am to 12 noon and Friday from 2pm to 6pm.
2. For the instruction and the achievement test: from May 12 to June 9 . . . scheduled to your convenience.

Where You Go:

1. Technology Building, IET department main office ask for Helmut Schörgmayer.

APPENDIX H

Application Form

Date: _____

Name: _____ SocSecNo: _____
last middle first

Sex: ___male ___female

Address: _____

Phone: _____

Best time to call: _____

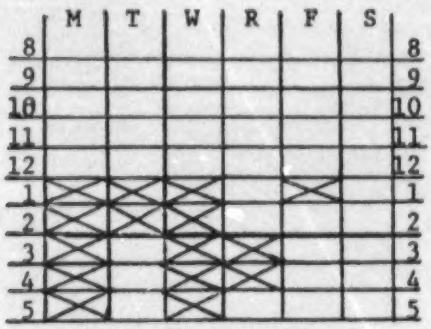
High school attended:
Name Adress Curriculum

_____ __general __college __vocat.

If BGSU student:
major: _____ minor: _____ Fr So Ju Se

Have you ever been employed in the area of equipment maintenance? __yes __no

Please mark the 3 hour blocks (as many as possible) you could schedule



For office use only

Score: _____ Accepted: _____

Scheduled for _____

Group: __concept. __specific

Time SIM: _____begin _____end _____time

Test	1	2	3	4
res.				
time				
score				

141

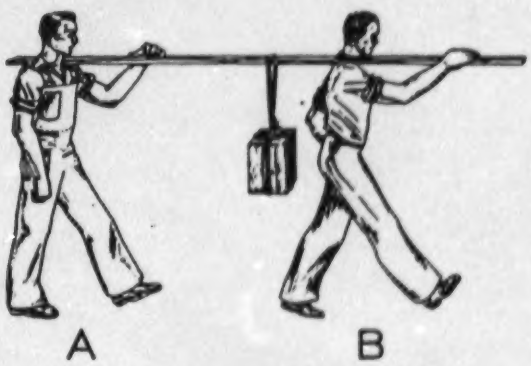
APPENDIX I

Bennett Mechanical Comprehension Test

DIRECTIONS

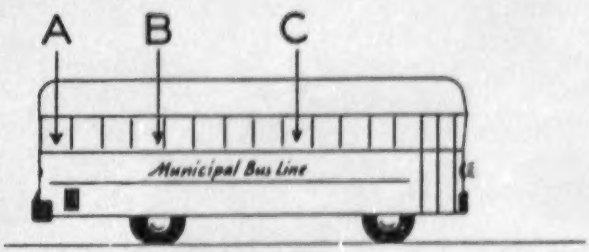
Fill in the requested information on your ANSWER SHEET.

Look at Sample X on this page. It shows two men carrying a weighted object on a plank, and it asks, "Which man carries more weight?" Because the object is closer to man "B" than to man "A," man "B" is shouldering more weight; so blacken the circle under "B" on your answer sheet. Now look at Sample Y and answer it yourself. Fill in the circle under the correct answer on your answer sheet.



X

Which man carries more weight? (If equal, mark C.)



Y

Which letter shows the seat where a passenger will get the smoothest ride?

On the following pages there are more pictures and questions. Read each question carefully, look at the picture, and fill in the circle under the best answer on the answer sheet. Make sure that your marks are heavy and black. Erase completely any answer you wish to change. Do not make any marks in this booklet.

DO NOT TURN OVER THE BOOKLET UNTIL YOU ARE TOLD TO DO SO.

The test contains 68 items. The directions and sample items are presented here.

APPENDIX J

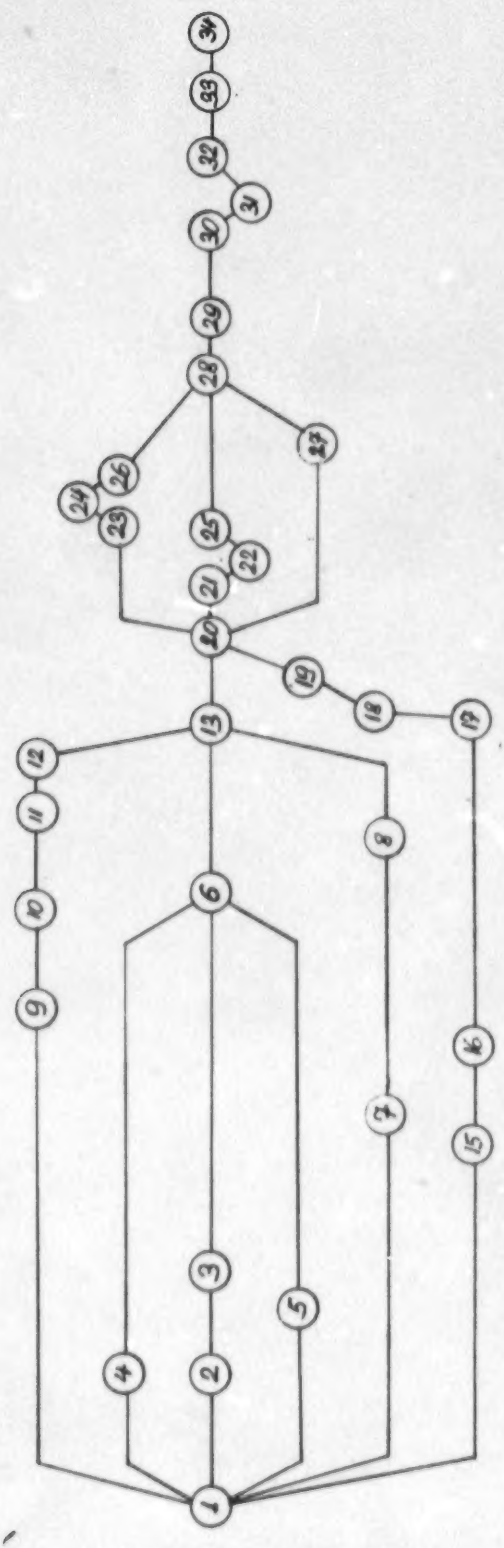
ATTITUDE INVENTORY

Please give us your opinions concerning your experience in the trouble-shooting study. There are no right or wrong answers, just tell us how you feel.

Key: SA ... strongly agree A ... agree
D ... disagree SD ... strongly disagree

SA	A	D	SD	
—	—	—	—	1) The simulator is a well-made representation of a real machine.
—	—	—	—	2) The arrangement of the components is well chosen.
—	—	—	—	3) Working with the apparatus was an interesting experience.
—	—	—	—	4) The self instructional module presents an interesting subject.
—	—	—	—	5) I like the way the subject is presented in the self instructional module.
—	—	—	—	6) I felt I learned something new and worthwhile.
—	—	—	—	7) The content of the self instructional module was easy.
—	—	—	—	8) Trouble-shooting is an easy task.
—	—	—	—	9) Trouble-shooting was an interesting experience.
—	—	—	—	10) I would be interested in a job that frequently involves trouble-shooting.
—	—	—	—	11) Without the information I received through the self instructional module, it would have been more difficult to trouble-shoot the simulator.
—	—	—	—	12) For effective trouble-shooting you have to have a detailed knowledge of the machine (simulator) with which you are dealing.
—	—	—	—	13) I think a job that frequently involves trouble-shooting can be quite stimulating.

APPENDIX K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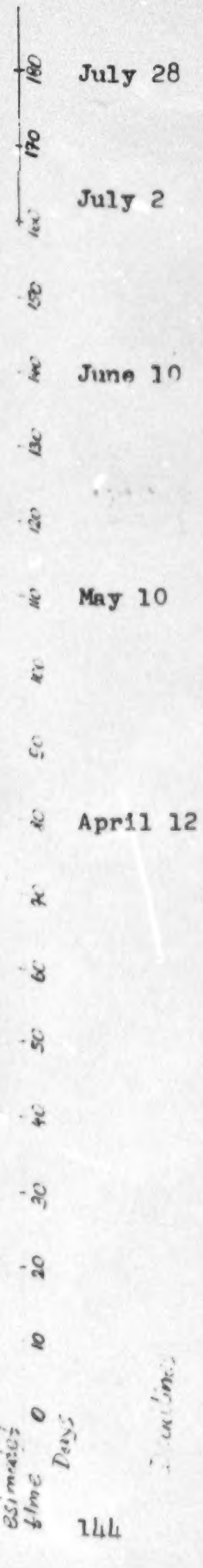
July 28
July 2
June 10
May 10
April 12
Estimated time
Days
144

PERT Events

1....Discuss committee members
2....Contact potential committee members
3....Acceptance by committee members

4....Writing Chapter 2 (review of the literature) of the proposal
5....Finish Chapter 1 (introduction) and Chapter 3 (procedures) of the proposal
6....Preliminary oral examination over the proposal
7....Design and assembly of the simulator
8....Prepare the simulator for the performance test
9....Behavioral objectives for the two training programs
10...Instructional decisions
11...Prepare both training programs
12...Critique of both training programs
13...Validate both training programs and the simulator
14...Prepare final form of the training programs and the simulator
15...Prepare budget for the experiment
16...Obtain funding for the experiment
17...Advertise for experimental subjects
18...Pretest candidates
19...Accept or reject candidates
20...Randomly divide trainees into three groups
21...Trainees (group 1) receive specific training
22...Trainees (group1) pass posttest
23...Trainees (group 2) receive conceptual training
24...Trainees (group 2) pass posttest
25...Collect data on specific approach with group 1 (performance test)
26...Collect data on conceptual approach with group 2 (performance test)
27...Collect data on the control group (performance test)
28...Analysis of the data
29...Outline final report
30...Write final report first draft
31...Submit final report to committee
32...Final oral examination
33...Write final report final draft
34...File library copies